

Review article

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Policy–Space Interactions in Urban and Regional Development: A Systematic Review with a Focus on Policy Spatial Footprints

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*Policy Spatial Footprint;
Spatial Planning;
Land Value Capture;
Network-Time Accessibility;
Urban Governance*

ABSTRACT

Abstract Against a backdrop of slowing urbanization, tightening climate constraints, and mounting fiscal pressures, understanding the spatial consequences of public policy is critical. However, empirical research often relies on coarse buffers or administrative units, hindering the isolation of effects from overlapping governance arrangements. This review synthesizes peer-reviewed literature, primarily published between 2020 and 2025, that links public policies—specifically land-use, transport, and environmental regulations—to spatially explicit outcomes such as land values, urban form, and emissions. Based on a systematic search of Web of Science and Scopus, we analyze studies that conceptualize policy as spatially delimited interventions with rigorous exposure metrics. notably, we highlight the Policy Spatial Footprint (PSF) framework. This approach converts regulatory clauses into quantifiable spatiotemporal geometries, facilitating causal identification strategies like staggered difference-in-differences models. Our synthesis reveals persistent sectoral fragmentation and a geographical bias toward major cities in Europe, North America, and China, while the Global South remains under-represented. Although methodological advances in spatial econometrics and digital twins are evident, open and standardized spatial policy datasets are scarce. We propose a "policy–space–outcome" framework anchored by PSF and advocate for future research integrating resilience and justice to evaluate how policy packages shape spatial development trajectories.

INTRODUCTION**Background: Why Policy–Space Interactions Matter**

Over the past decade, debates on urban sustainability have shifted from managing rapid greenfield expansion to governing the reconfiguration of existing built-up areas under climate, demographic and fiscal constraints. Empirical work shows that urban land use and spatial form strongly condition energy demand and car-

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bon emissions, especially through transport and buildings (Creutzig et al., 2015; Ewing & Cervero, 2010; Glaeser & Kahn, 2010; Seto et al., 2012). As the scope for extensive outward expansion diminishes in many regions, the key levers shaping spatial structure have become institutional and policy-based—zoning and building regulations, infrastructure investment, environmental standards and fiscal instruments—rather than simply the availability of developable land (Leibowicz, 2020; Wang & Jin, 2025).

This shift is particularly visible in climate and disaster policy, where spatial planning is framed as a core instrument for mitigation and adaptation. Reviews of land use, spatial planning and carbon outcomes highlight how urban form, land-use mix and development intensity mediate emissions, while disaster-risk and adaptation studies emphasise risk-sensitive planning, zoning of floodplains and coasts, and resilience-oriented infrastructure policies (Creutzig et al., 2015; Menoni, 2025; Nowak et al., 2023, 2024; Seto et al., 2012; Voskamp et al., 2021). In these debates, the central challenge is less whether policy matters and more how different policy mixes translate into measurable changes in land use, morphology, accessibility and ecosystem functions.

Despite a long tradition of research on planning systems, regulatory instruments and governance arrangements, many studies still treat policy as an abstract context or as exogenous control variables, while focusing empirically on spatial patterns and processes. Environmental policy integration (EPI) research, for example, documents the difficulties of aligning sectoral policies with environmental goals but rarely connects these governance dynamics to fine-grained spatial outcomes (Mickwitz, 2003; Runhaar et al., 2014; van Oosten et al., 2018; van den Ende et al., 2025). Work on nature-based solutions and ecosystem-based adaptation similarly examines policy mixes and institutional conditions, yet often stops at programme adoption or project inventories, without tracing how instruments reshape land-use configurations or accessibility landscapes (Kauark-Fontes et al., 2023; van der Jagt et al., 2023; Wamsler, 2015). In land and transport economics, analyses of transit investments and value capture mechanisms demonstrate substantial impacts on land values and development intensity around stations and corridors (Cervero & Kang, 2011; Cervero & Murakami, 2009; Gong et al., 2021; Medda, 2012; Mohammad et al., 2013; van Zoest et al., 2024), but they often rely on generic proximity measures or administrative dummies to represent “policy exposure”, only partially capturing the heterogeneous spatial reach of modern instruments such as overlay zones, special assessment districts or hazard-specific regulations.

Defining “Policy” and “Space”

In this review, “policy” is understood not as isolated laws or plans but as configurations of instruments and

governance arrangements that shape spatial development over time. Building on work in environmental policy integration and nature-based solutions governance, policy is treated as a multi-dimensional mix of instruments that differ in mode of steering and spatial reach (Dorado-Rubín et al., 2025; Kauark-Fontes et al., 2023; Runhaar et al., 2014; van der Jagt et al., 2023; van den Ende et al., 2025). Four broad categories are distinguished. Regulatory and planning instruments include statutory spatial plans, zoning ordinances, building codes, development control regimes, hazard-zone designations and environmental standards. Fiscal and economic instruments encompass land-value capture mechanisms, impact fees, development charges, property-tax reforms, subsidies and tax incentives linked to spatially targeted objectives (Gong et al., 2021; Medda, 2012; Mohammad et al., 2013; van Zoest et al., 2024; Walters, 2013). Infrastructural and investment policies cover capital expenditure on transport, utilities, green and blue infrastructure and public facilities (Cervero & Kang, 2011; Cervero & Murakami, 2009; Leibowicz, 2020). Organisational and collaborative arrangements include coordination mechanisms between levels of government, inter-municipal agreements, public–private partnerships and participatory planning processes (Masuda et al., 2021; Menoni, 2025; van Oosten et al., 2018).

“Space” is used in a broad sense to encompass physical land-use and morphological patterns, network-based accessibility, ecological and carbon dynamics, and socially differentiated exposure to risks and amenities. Spatial outcomes include land-use type and intensity, urban form and density, and the topology of street and transit networks that underpin multi-scalar accessibility (Cervero & Murakami, 2009; Gong et al., 2021; Leibowicz, 2020; Seto et al., 2012; Wang & Jin, 2025). They also include ecological and ecosystem-service dimensions, where policy decisions about land conversion, conservation and restoration affect carbon stocks, habitat connectivity and ecosystem-service provision, increasingly modelled with spatially explicit tools (Goldstein et al., 2012; Grêt-Regamey et al., 2017; Ronchi, 2018; Voskamp et al., 2021). Spatial structure is inherently temporal and relational: accessibility and exposure depend on network structure, travel times and service frequencies, themselves shaped by policy decisions (Leibowicz, 2020; Medda, 2012). In climate and disaster fields, spatial outcomes include socially differentiated risk exposure and adaptive capacity, for example through settlement patterns in floodplains or heat-prone neighbourhoods that reflect zoning, housing policies and historical discrimination (Menoni, 2025; Nowak et al., 2023, 2024; Wamsler, 2015).

Within this review, “policy–space interactions” therefore refers to the ways in which concrete instruments and governance arrangements produce, stabilise or transform spatial outcomes across these built, ecological, network and social dimensions. The focus is on

approaches that treat both policy and space as empirically observable and quantifiable, ideally with explicit geometries, temporal markers and causal identification strategies. The Policy Spatial Footprint (PSF) framework occupies a central position because it operationalises policy as a spatial–temporal footprint that can be intersected with land parcels, networks or ecological units (Xie et al., 2025), but it is viewed as one member of a broader methodological shift towards spatially explicit policy analysis.

Objectives and Research Questions

Against this backdrop, the review aims to systematise recent advances in the study of policy–space interactions, with particular attention to methods that make policy exposure explicit in spatial terms and link it to outcomes using quasi-experimental or otherwise rigorous empirical designs. Between 2020 and 2025, several subfields have produced partial overviews of related topics, including land-use and spatial-planning impacts on carbon emissions (Wang & Jin, 2025), disaster-risk-sensitive urban planning and climate adaptation (Menoni, 2025; Nowak et al., 2023, 2024), tools for planning green infrastructure and nature-based solutions (Kauark-Fontes et al., 2023; Voskamp et al., 2021; Wamsler, 2015), and land-value capture for transport investment (Gong et al., 2021; Medda, 2012; van Zoest et al., 2024). However, there is still no integrative synthesis that compares how different policy domains conceptualise and measure policy exposure, which spatial outcomes they prioritise, and how they address causality, scale and governance complexity.

The first objective is therefore to review empirical and theoretical studies published mainly between 2020 and 2025 that explicitly analyse how policy instruments and mixes affect spatial outcomes across domains such as climate and environmental planning, transport and land-value capture, and ecosystem services and nature-based solutions. The second objective is to compare how these domains define and operationalise the spatial reach of policies, including traditional distance- and buffer-based measures, administrative boundaries and newer approaches such as network-time isochrones and polygon-based policy footprints (Goldstein et al., 2012; Grêt-Regamey et al., 2017; Leibowicz, 2020; Xie et al., 2025). The third objective is to position PSF relative to other spatial policy representations, clarifying its contributions and limitations and exploring how PSF-like ideas could be adapted to sectors beyond transport and land-value capture. Finally, the review aims to propose a synthetic policy–space–outcome framework that can guide future empirical work and support cross-fertilisation between currently fragmented literatures.

These aims translate into four guiding research questions: (1) Which types of policy instruments and policy mixes have been most frequently examined in relation to spatial outcomes, and how does this vary

across domains such as climate adaptation and mitigation, transport and nature-based solutions (Kauark-Fontes et al., 2023; Menoni, 2025; Nowak et al., 2023, 2024; van der Jagt et al., 2023)? (2) How is “policy exposure” conceptualised and quantified, and what are the main strengths and weaknesses of approaches ranging from traditional proximity measures and administrative indicators to ecological units and PSF-style network-time and polygonal footprints (Goldstein et al., 2012; Grêt-Regamey et al., 2017; Leibowicz, 2020; Xie et al., 2025)? (3) Which spatial outcomes—such as land values, development density, accessibility, risk exposure or ecosystem services—are prioritised, and at what spatial and temporal scales are these effects evaluated (Cervero & Murakami, 2009; Gong et al., 2021; Masuda et al., 2021; Wang & Jin, 2025)? (4) Where do important gaps remain in terms of geographic coverage, city types and scales of analysis—for example small and medium-sized cities, informal settlements, peri-urban landscapes or cross-jurisdictional governance—and how might PSF-like approaches help address these gaps (Creutzig et al., 2015; Seto et al., 2012; van Oosten et al., 2018; van Zoest et al., 2024)?

Scope and Structure of the Review

The review focuses on peer-reviewed journal articles published between 2020 and 2025 in English-language SCI and SSCI-indexed journals, complemented by earlier theoretical and methodological contributions that remain central to current debates. The disciplinary scope spans land science, urban and regional planning, transport studies, environmental policy and governance, and sustainability science. Studies are included if they (i) analyse at least one identifiable policy instrument or policy mix; (ii) assess spatial outcomes using explicit spatial data, such as land-use maps, parcel records, accessibility measures, ecosystem-service maps or value surfaces; and (iii) provide an empirical link between policy instruments and these outcomes, whether descriptive, correlational or causal. Both single-city and comparative multi-city or multi-country studies are considered, at scales ranging from neighbourhoods and corridors to metropolitan regions and national spatial planning systems.

Within this corpus, particular attention is given to studies that innovate in how policy exposure is conceptualised and measured, including work in ecosystem services and nature-based solutions that maps policy-relevant units and scenarios (Goldstein et al., 2012; Grêt-Regamey et al., 2017; Ronchi, 2018; Voskamp et al., 2021), climate and disaster-risk planning that links regulatory and investment instruments to spatial risk patterns (Menoni, 2025; Nowak et al., 2023, 2024; Wamsler, 2015), and transport–land-value studies that refine notions of accessibility and investment reach (Cervero & Kang, 2011; Cervero & Murakami, 2009; Gong et al., 2021; Medda, 2012; Mohammad et al., 2013; van Zoest et al., 2024). The PSF article is treated

as a central exemplar because it formalises policy exposure using network-time and parcel-level geometries that are directly amenable to causal identification (Xie et al., 2025).

The remainder of the article is structured as follows. Section 2 details the systematic search, screening and coding procedures. Section 3 develops a conceptual lens that links policy instruments, multi-level governance and spatial exposure, with PSF presented as one concrete implementation within a wider policy–space–outcome framework. Section 4 summarises the empirical corpus across policy domains, spatial scales and world regions, while Section 5 compares how different studies operationalise policy exposure and identify causal effects. Section 6 discusses governance implications, and Section 7 proposes an integrative framework for future work. Section 8 outlines a forward-looking research agenda, and Section 9 concludes.

METHODS: LITERATURE SEARCH AND REVIEW PROTOCOL

Database Selection and Search Strategy

The review adopts a transparent and replicable search strategy that follows established guidance for systematic and structured literature reviews in the social sciences, planning and environmental policy fields (Moher et al., 2009; Page et al., 2021; Petticrew & Roberts, 2006; Snyder, 2019; Tranfield et al., 2003). The core bibliographic databases are Web of Science Core Collection and Scopus, which jointly provide broad coverage of SCI/SSCI-indexed journals and robust tools for filtering by subject category, document type and publication year (Grant & Booth, 2009; Xiao & Watson, 2019). Using multiple databases reduces the risk of disciplinary blind spots in a field that spans land-system science, urban and regional planning, environmental economics, transport studies and public health (Berrang-Ford et al., 2015; Menoni, 2025; Wang & Jin, 2025).

Searches were restricted to peer-reviewed journal articles published in English between January 2020 and November 2025. This temporal window captures the surge of interest in explicit policy–space modelling and causal identification strategies applied to spatial data, while allowing the inclusion of recent methodological innovations such as the PSF framework and network-time exposure metrics (Page et al., 2021; Snyder, 2019; Wang & Jin, 2025; Xie et al., 2025). Foundational conceptual and methodological works predating 2020, including classic contributions to spatial econometrics and causal inference, are added through backward snowballing to situate recent studies in a longer methodological genealogy (Anselin, 1988; LeSage & Pace, 2009; Moran, 1950; Callaway & Sant’Anna, 2021).

The search strings combine terms for “policy” with terms for “space” using Boolean operators. Policy terms include “policy”, “regulation”, “zoning”, “ordinance”, “planning”, “governance”, “fiscal instrument”, “tax”, “subsidy”, “impact fee”, “value capture” and “nature-based solutions”. Spatial terms include “spatial”, “land use”, “land-use change”, “built-up area”, “urban form”, “urban morphology”, “spatial structure”, “accessibility”, “network time”, “exposure” and “spatial footprint”. In Web of Science, a typical query was: TS = ((policy OR regulation* OR zoning OR “land-use plan*” OR “value capture” OR “impact fee*”) AND (spatial OR “land use” OR “urban form” OR “spatial structure” OR “network-time” OR “spatial footprint”)), refined by document type (article) and time span (2020–2025). Two focused strings—(“policy spatial footprint” OR “PSF”) and (“network-time exposure” OR “network travel time” AND policy)—were used to capture PSF-type studies that transform policy texts into machine-readable geometries and network-time buffers (Xie et al., 2025) and related approaches in climate-sensitive spatial policy (Menoni, 2025; Voskamp et al., 2021).

To limit publication bias towards large, well-indexed publishers, database searches were complemented by three forms of snowballing. First, reference lists of key review articles on land-use planning and carbon emissions, disaster-risk-sensitive urban planning and urban climate adaptation tools were screened for additional eligible studies (Berrang-Ford et al., 2015; Menoni, 2025; Voskamp et al., 2021; Wang & Jin, 2025). Second, forward citation searches were conducted on a small set of seminal policy–space studies, including PSF and classic hedonic valuation studies of environmental and land-use regulations (Chay & Greenstone, 2005; Rosen, 1974; Xie et al., 2025). Third, targeted searches in leading field journals (e.g. *Land, Sustainability*, *Journal of the American Planning Association*, *Regional Environmental Change*, *Journal of Regional Science*) were used to ensure that special issues on zoning, climate policy and spatial planning were not missed because of database indexing idiosyncrasies.

Inclusion and Exclusion Criteria

The inclusion criteria focus the review on studies that (1) analyse an explicit public policy or planning instrument, (2) operationalise spatial exposure or spatial structure in an empirically measurable way and (3) report spatially explicit outcomes. First, studies must examine a public policy broadly defined to include statutory regulations and zoning ordinances, spatial plans and regulatory master plans, fiscal and tax instruments with spatial incidence (e.g. property-tax reforms, land-value capture schemes), transport and infrastructure policies, environmental and climate policies or formalised governance arrangements such as conservation zoning or nature-based solutions programmes (Grant & Booth, 2009; Menoni, 2025; Wang & Jin, 2025). General discussions of “governance” or “institutions” without a

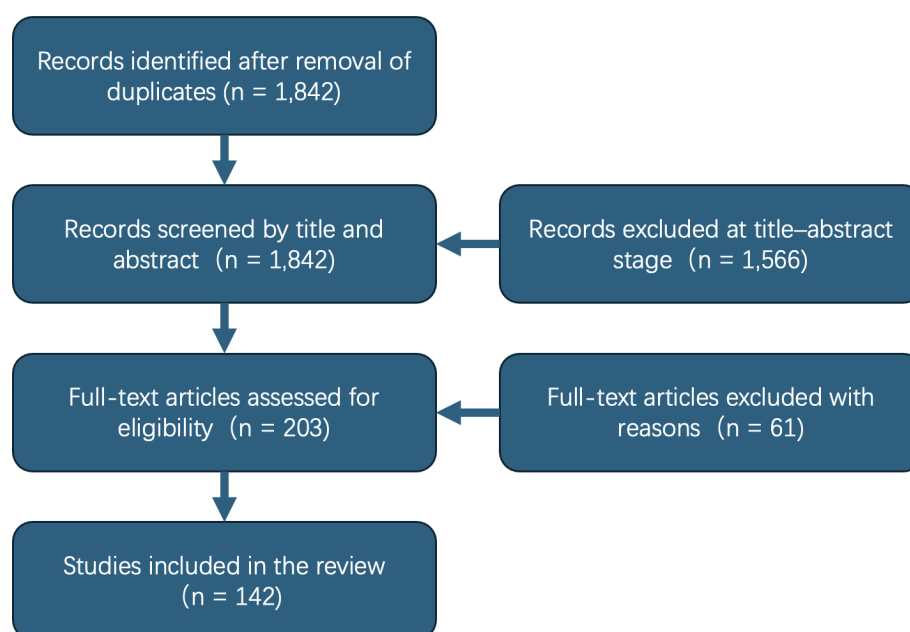


Figure 1 | PRISMA flow diagram for study identification, screening and inclusion

clearly identified instrument, or papers where policy is invoked only as context, are excluded. This reflects the review's aim to map how concrete instruments, rather than abstract governance ideals, translate into spatial footprints and exposures.

Second, eligible studies must contain at least one spatially explicit measure of policy exposure, spatial structure or spatial outcome. Acceptable exposure measures include distance to regulatory boundaries, inclusion within zoning polygons or plan designations, Euclidean or network travel time to new infrastructure, and PSF-type metrics that link legal clauses to network-time buffers or spatial eligibility areas (Kwan, 2012; Xie et al., 2025). Eligible outcomes include land prices or rents, land-use change and built-up expansion, changes in urban form and density, hazard or pollution exposure, ecosystem-service or carbon-emission indicators and distributional outcomes such as segregation or differential environmental risks (Berrang-Ford et al., 2015; Ewing & Cervero, 2010; Seto et al., 2012; Wang & Jin, 2025). Studies that discuss spatial concepts purely qualitatively, or that model hypothetical scenarios without a concrete policy instrument, are excluded.

Third, only peer-reviewed journal articles written in English are included. Conference papers, theses, book chapters, technical reports and policy briefs are excluded, even when they present sophisticated spatial analyses, because their peer-review status and long-term accessibility are harder to verify systematically (Snyder, 2019; Xiao & Watson, 2019). Grey-literature materials, such as early pilots of local PSF-like approaches or internal governmental network-time analyses, are used

qualitatively to contextualise gaps but are not coded as part of the formal sample. Studies must provide sufficient methodological detail to identify the policy instrument, exposure metric and spatial outcome. Articles that do not clearly describe their policy intervention, do not specify how spatial units and exposure are defined, or conflate multiple policies without disaggregated analysis are excluded at the full-text stage. Finally, studies whose primary question is why policies are adopted earlier in some places than others, or why their design differs across jurisdictions, are only included if they also analyse spatially disaggregated outcomes of the policies themselves (Angrist & Pischke, 2009; Callaway & Sant'Anna, 2021).

Screening, Coding and Synthesis Procedures

The screening procedure follows PRISMA 2009 and PRISMA 2020 guidelines for transparent reporting of systematic reviews (Moher et al., 2009; Page et al., 2021). After removal of duplicates, the database searches yielded 1,842 records. Title- and abstract-screening reduced this to 276 records, of which 203 articles were retrieved for full-text assessment. Applying the inclusion and exclusion criteria resulted in 142 articles being retained for coding and synthesis. A PRISMA flow diagram (**Figure 1**) documents the number of records at each stage and the main reasons for exclusion.

For each included article, a structured coding framework is applied. Bibliographic fields capture authorship, year, journal and discipline; contextual fields record the country or region, spatial scale (parcel,

neighbourhood, city, region, national) and study period. Policy-related fields classify the domain (e.g. land-use and zoning, transport and infrastructure, environmental and climate, social and health, rural and peri-urban), instrument type (regulatory, fiscal/tax, informational or voluntary, organisational and governance, or multi-instrument packages) and whether the policy is primarily enabling, restrictive or redistributive (Berrang-Ford et al., 2015; Grant & Booth, 2009; Menoni, 2025). Spatial-exposure fields record how policy exposure is operationalised: binary inclusion in a zoning or PSF polygon; Euclidean buffers around infrastructure; distance-decay functions; network-based travel time to PSF boundaries, stations or facilities; or composite eligibility indices constructed from multiple criteria (Kwan, 2012; Xie et al., 2025). Outcome-related fields characterise the main spatial outcomes analysed, including land-value or rent capitalisation, land-use conversion or built-up expansion, changes in urban form and density, carbon emissions and energy use, ecosystem-service provision, disaster risk and climate-hazard exposure, and social and health inequalities (Chay & Greenstone, 2005; Ewing & Cervero, 2010; Rosen, 1974; Seto et al., 2012; Voskamp et al., 2021; Wang & Jin, 2025). Methodological fields distinguish between descriptive spatial analysis, spatial econometric models, quasi-experimental designs, simulation models and mixed-methods or qualitative GIS approaches (Abadie et al., 2010; Anselin, 1988; Callaway & Sant'Anna, 2021; Elhorst, 2014; LeSage & Pace, 2009; Snyder, 2019). **Table 1** summarises the coding dimensions and categories.

To enhance reliability, the coding protocol was piloted on a random subset of 20 articles spanning different policy domains, spatial scales and methodological approaches and refined to reduce ambiguity in category boundaries. Two coders then independently coded all articles in the final corpus, with discrepancies discussed and resolved by consensus. Inter-coder agreement, monitored using Cohen's kappa for the main categorical variables (policy domain, instrument type, spatial exposure metric and outcome category), ranged between 0.78 and 0.88, which is commonly interpreted as substantial agreement (Stemler, 2001). A random 10% subsample was re-coded midway through the process as an additional reliability check. Given the heterogeneity of policy instruments, spatial scales, identification strategies and outcome measures, formal meta-analysis of effect sizes is neither feasible nor substantively meaningful. Instead, the synthesis combines descriptive statistics of coded variables with a structured narrative comparison of how studies operationalise policy exposure and address confounding, reporting exact effect sizes only for illustrative cases.

Limitations

The review has several methodological limitations. Restricting the search to English-language, peer-re-

viewed journal articles indexed in Web of Science and Scopus introduces language and database biases, privileging research produced in and about high-income countries (Berrang-Ford et al., 2015; Snyder, 2019). Empirical work on policy-space interactions in government reports, consultancy documentation or local-language journals is likely under-represented. Focusing on 2020–2025 captures recent methodological innovations but means that earlier generations of policy-space research, such as classic hedonic analyses of environmental regulation or early spatial econometric studies of zoning, are covered only selectively through backward snowballing (Chay & Greenstone, 2005; Rosen, 1974; Tiebout, 1956). Coding of policy instruments, spatial exposure metrics and outcomes inevitably involves judgement, even with a detailed codebook and inter-coder reliability checks (Stemler, 2001); comprehensive spatial plans that embed fiscal instruments and environmental regulations, or hybrid exposure metrics that combine zoning, accessibility and network-time measures, are particularly challenging to classify. Finally, by design the review gives particular attention to studies that explicitly quantify policy spatial footprints, network-time exposure or similar constructs linking legal or policy text to spatial geometries, such as PSF (Xie et al., 2025) and related approaches in climate adaptation and nature-based solutions planning (Menoni, 2025; Voskamp et al., 2021). This emphasis is warranted by the objective of tracing methodological innovation, but it risks biasing the corpus towards data- and method-intensive studies. There is therefore a need for complementary syntheses that connect these advanced methods to more practice-oriented evaluations in low- and middle-income contexts and link simple spatial indicators used in local planning practice to more elaborate exposure metrics.

CONCEPTUAL FOUNDATIONS: POLICY INSTRUMENTS, SPATIAL DIMENSIONS AND PSF

Typologies of Spatial Policy Instruments

Debates on policy instruments provide the first foundation for analysing how public action reshapes space. Classical work distinguishes instruments according to the primary “mode of governing”. Bemelmans-Videc et al. (2017) group instruments into “carrots, sticks and sermons,” corresponding to economic incentives, regulatory obligations and informational or persuasive tools. Lascoumes and Le Galès (2007) reconceptualise instruments as socio-technical devices that embody particular representations of policy problems and reorder relations between state and society, emphasising that the same broad instrument family can perform very different functions depending on design details. Howlett (2018, 2023) further stresses that instrument choice is constrained both by contextual “selection environments”

Table 1 | Coding framework for policy instruments, spatial exposure and outcomes

Coding dimension	Categories (examples)	Description
Contextual fields	Country or region; city or metropolitan area; spatial scale (parcel, neighbourhood, city, region, national); study period	Records the basic context of each study, including where it is carried out, at which spatial scale the analysis is conducted, and which years or periods are covered by the empirical data.
Policy domain	Land-use and zoning; transport and infrastructure; environmental and climate policy; social and health policy; rural and peri-urban development	Classifies the substantive area of public policy under investigation, recognising that many policies are cross-cutting but typically anchored in one dominant domain.
Instrument type	Regulatory instruments (e.g. zoning ordinances, building codes); fiscal and tax instruments (e.g. taxes, subsidies, development charges, land-value capture schemes); informational or voluntary instruments (e.g. labelling, guidance, awareness campaigns); investment and infrastructure provision; multi-instrument policy packages	Distinguishes the main type of instrument or combination of instruments used to implement the policy, following standard typologies in public policy analysis and urban governance.
Instrument function	Enabling; restrictive; redistributive	Indicates whether the instrument primarily enables and facilitates certain activities, restricts or prohibits them, or redistributes resources and opportunities across groups and places.
Spatial scale	Parcel or neighbourhood; city or municipal; metropolitan or regional; national or multi-level	Records the main spatial decision-making level at which the policy is designed and/or evaluated, recognising that many policies operate across multiple levels but are implemented at a dominant scale.
Spatial exposure metric	Binary inclusion in a zoning district or PSF polygon; Euclidean buffers around infrastructure or facilities; distance-decay functions; administrative-unit assignment; network-based travel time to PSF boundaries, stations or facilities; composite eligibility indices constructed from multiple criteria	Describes how policy exposure is operationalised in spatial terms, ranging from simple inclusion in mapped polygons to more complex measures based on distance, travel time or multi-criteria eligibility indices.
Outcome category	Land values or property prices (including hedonic and repeat-sales models); land-use conversion or built-up expansion; changes in urban form and density; carbon emissions and energy use; ecosystem-service provision; disaster risk and climate-hazard exposure; social and health inequalities	Captures the primary spatial outcomes analysed in the study, with multiple codes assigned where a study reports several outcome types.
Methodological approach	Descriptive spatial analysis; spatial econometric models (e.g. spatial lag, spatial error, spatial Durbin models); quasi-experimental designs (difference-in-differences, staggered adoption, synthetic control, regression discontinuity); simulation models (cellular automata, agent-based models); mixed-methods or qualitative GIS approaches	Classifies the dominant analytical approach used to link policy exposure to spatial outcomes, with attention to whether causal identification strategies are employed.
World region and income group	Europe; North America; East Asia; other high-income regions (e.g. Australia and New Zealand); low- and middle-income regions (e.g. Latin America, Africa, South and Southeast Asia)	Groups countries into broad world regions and income groups, allowing the review to assess geographical and income-related imbalances in the evidence base.

and by policy-makers' capacities, so that the observable mix of instruments is the outcome of incremental layering and past choices rather than technocratic optimisation.

More recent work shifts from single instruments to "policy mixes" and their internal consistency. Capano and Howlett (2020) argue that instrument analysis must move beyond classificatory schemes to examine how combinations of regulatory, economic, informational and organisational tools interact over time. They distinguish between instrument logics (e.g., command-and-control versus market-based) and implementation modalities (e.g., procedural versus substantive tools), showing that certain combinations are prone to conflict or redundancy. Mukherjee et al. (2021) connect policy capacities with instrument effectiveness, highlighting that sophisticated instruments such as dynamic carbon pricing or performance-based planning obligations require analytical and administrative capacities that are unevenly distributed across jurisdictions. Bali et al. (2021) and de Vries (2021) bring procedural tools—participatory processes, consultation requirements, impact assessment, and sequencing rules—into the instrument typology, showing that they shape which spatial options are considered politically and how distributive conflicts are framed.

Within this broader tradition, spatial planning and land-use governance are increasingly analysed through their own instrument palettes. Stead (2021) proposes a typology of spatial planning tools that distinguishes statutory land-use plans and zoning, development control and permits, infrastructure provision, fiscal and financial instruments (e.g., development charges, value capture), information and advisory tools (e.g., design guides), and collaborative or contractual instruments (e.g., public–private partnerships, strategic spatial frameworks). OECD (2017) and Krawchenko and Tomaney (2023) show that countries differ substantially in how they combine these instruments: some rely heavily on hierarchical statutory plans and ex ante zoning, whereas others emphasise negotiated development agreements, performance-based standards, or strategic regional frameworks that guide but do not legally bind local decisions. Restemeyer and Witte (2024) analyse Dutch integrated spatial policies as "instrument palettes" for spatial quality, demonstrating that effective place-based governance requires context-specific blends of permissive zoning, protective designations, targeted subsidies, and participatory design processes rather than any single "best" instrument.

Environmental and climate governance literatures similarly stress instrument diversity but place particular

emphasis on environmental policy integration. Kirsop-Taylor et al. (2022) show how nature-based solutions in European cities rely on hybrid mixes of statutory spatial plans, green infrastructure standards, funding programmes, and soft coordination mechanisms that traverse departmental boundaries. Corgo and Freitas (2024) find that climate-adaptation-oriented planning increasingly combines regulatory instruments (e.g., flood zoning), economic incentives (e.g., subsidies for green roofs), and information tools (e.g., hazard maps), but that integration across sectors remains partial. A broader wave of research on policy integration and multi-level policy mixes demonstrates that spatial outcomes emerge from layered, often path-dependent combinations of instruments adopted at different government levels and time periods rather than from isolated planning decisions (Cejudo & Trein, 2023; Dorado-Rubín et al., 2025; Trein et al., 2023).

These developments have important implications for spatial analysis. First, they suggest that any empirical account of “policy–space interactions” must move from single-instrument evaluations (e.g., of a zoning change or a congestion charge) to analysis of how instrument bundles jointly condition land use, accessibility and environmental quality. Second, the growing attention to procedural and organisational tools implies that spatial impacts may arise not only from explicit spatial rules (such as floor-area ratios or building height limits) but also from agenda-setting procedures, consultation mechanisms and cross-sectoral coordination routines that determine which spatial configurations become politically feasible. Finally, typologies that are not spatially explicit need to be complemented by frameworks that map how specific instrument configurations are inscribed into space, which is precisely the gap that the Policy Spatial Footprint (PSF) framework seeks to address.

Spatial Dimensions of Policy Impact

Policy instruments operate across multiple spatial dimensions that are now well characterised in the urban studies and environmental sciences literature. A first dimension concerns land-use intensity, functional mix and built-form characteristics. Ewing and Cervero’s (2010) meta-analysis of the “3D” variables—density, diversity, and design—demonstrates that compact, mixed-use and well-designed neighbourhoods significantly reduce vehicle kilometres travelled, with implications for both congestion and emissions. Glaeser and Kahn (2010) and Danylo et al. (2019) show that variations in land-use patterns and building typologies drive large differences in per-capita carbon emissions across cities and neighbourhoods, while more recent reviews examine how specific urban-form metrics (e.g., building height, floor-area ratio, sky-view factor) affect building operational energy demand (Liu et al., 2025). These findings imply that instruments such as density zoning, plot-ratio controls, and urban growth boundaries have

direct implications for emissions and energy use, even when they are not framed as climate policy.

A second dimension relates to the broader urban morphology and the internal spatial structure of metropolitan regions. Work on polycentric mega-city regions highlights how the distribution of employment and services across multiple nodes affects commuting patterns, congestion, and spatial equity in access to opportunities (Hall & Pain, 2006). Morphological measures of centre hierarchy, commuting flows and inter-urban linkages have been used to characterise polycentricity and to evaluate whether strategic spatial plans succeed in rebalancing development away from congested cores. Spatial planning instruments such as transit-oriented development (TOD) zoning, regional strategic plans, and land-value capture mechanisms for station-area development can intentionally steer this internal morphology, although evidence suggests that formal plans and actual development trajectories often diverge under market pressure and fragmented governance (Krawchenko & Tomaney, 2023; Stead, 2021).

Third, policy–space interactions increasingly focus on ecological and carbon spaces. Studies mapping greenhouse-gas emissions at fine spatial resolution show highly uneven emission hotspots across urban fabrics, with detached housing and car-dependent suburbs contributing disproportionately to residential and transport emissions (Danylo et al., 2019; Glaeser & Kahn, 2010). Health impact assessments further demonstrate that urban and transport planning decisions determine exposure to multiple risks, including air pollution, traffic injuries and physical inactivity (Rojas-Rueda et al., 2019). These findings have led to new planning instruments—emission caps for specific zones, low-emission districts, “15-minute city” street reallocation, and nature-based buffers—that are explicitly designed to reshape emission and exposure landscapes rather than simply accommodate growth. Nature-based solutions research shows how zoning for green infrastructure, ecological corridors and blue–green networks can be treated as spatial instruments that manage both ecosystem services and climate risks (Corgo & Freitas, 2024; Qiu et al., 2022; Lai & Zoppi, 2024).

A fourth spatial dimension is socio-spatial and health inequality. Environmental justice studies reveal that low-income and minority communities tend to reside closer to pollution sources and further from high-quality green spaces, even in contexts where aggregate green coverage is high (Twohig-Bennett & Jones, 2018; Wolch et al., 2014). Recent analyses in rapidly urbanising Chinese cities find pronounced socioeconomic inequalities in green-space distribution and access, driven by redevelopment patterns and high-end residential enclaves (Hou et al., 2024; Zhu et al., 2025). Network-based assessments of exposure to green space and other amenities show that using Euclidean buffers underestimates inequalities compared with network-time mea-

asures that incorporate actual route options and travel times (Song et al., 2018; Labib et al., 2021). In this context, spatial policy instruments—such as inclusionary zoning, minimum green-space standards per capita, or targeted investment in underserved neighbourhoods—are increasingly assessed in terms of their capacity to reduce spatialised inequalities rather than only to meet aggregate targets.

Taken together, these strands suggest that policy–space interactions must be conceptualised as multi-dimensional: the same instrument can simultaneously affect built-form intensity, metropolitan morphology, emissions and health inequalities. For analytical purposes, the review therefore treats “spatial impact dimensions” as a set of partly overlapping outcome domains—built environment, ecological and carbon spaces, and socio-spatial justice—that provide a common language to compare heterogeneous policy instruments and sectors.

Multi-Level Governance, Policy Space and Spatial Planning

The spatial reach of instruments is mediated by multi-level governance arrangements that allocate planning powers and fiscal resources across scales. Nadin et al. (2021) show that European spatial planning has evolved towards more integrated, adaptive and participatory models, yet strong national frameworks continue to constrain local discretion, particularly in countries with detailed statutory planning hierarchies. Hickmann et al. (2021) locate cities within multi-level climate governance architectures, demonstrating that local climate and land-use plans are nested within international agreements, national mitigation targets and sectoral regulations, creating both opportunities for upward influence and constraints from above. OECD (2017) and Krawchenko and Tomaney (2023) extend this perspective to land-use governance more broadly, proposing conceptual frameworks that distinguish between the formal allocation of competences (e.g., who can zone or levy development charges), fiscal relations (e.g., property-tax assignments, intergovernmental transfers) and informal coordination mechanisms (e.g., metropolitan partnerships).

Within these architectures, “policy space” denotes the discretionary room that sub-national governments have to adapt or combine instruments to local conditions. Banikoi et al. (2024) show that in Sub-Saharan African contexts, local governments’ policy space in land-use and spatial planning is often severely constrained by centralised legal frameworks and donor-driven project logics, which reduces their capacity to address informality and environmental risks. Dorado-Rubín et al. (2025) analyse European urban policies as multi-level policy mixes, arguing that local spatial policies emerge from the interplay of EU directives, national frameworks and municipal initiatives; they stress that genuine integration requires not only horizontal coordi-

nation across sectors, but also vertical alignment of objectives and instruments. Cejudo and Trein (2023) and Trein et al. (2023) further highlight that policy integration can follow different pathways—such as layering, displacement or conversion of existing instruments—and that these trajectories are shaped by institutional capacities and political coalitions at each level of government.

Spatial planning is therefore both a distinct policy domain and a site where multi-level policy mixes materialise. National governments typically control high-level instruments such as infrastructure investment programmes, environmental regulations and broad zoning categories, while regional and local governments deploy more fine-grained instruments—detailed land-use plans, development permits, design codes, and municipal taxes or fees. Stead (2021) and Restemeyer and Witte (2024) show that the effectiveness of spatial planning tools depends on how they are embedded in these multi-level regimes: local experiments with nature-based solutions or value-capture instruments are fragile if they are not supported by higher-level frameworks that provide legal certainty and stable revenue streams. At the same time, procedural instruments such as participation requirements, strategic environmental assessment and inter-municipal coordination forums can expand local policy space by enabling municipalities to negotiate exceptions or experiment with novel spatial practices (Bali et al., 2021; de Vries, 2021).

Conceptually, this implies that “policy–space interactions” cannot be reduced to a single regulatory change at one level of government. Instead, spatial outcomes such as transit-oriented development corridors, ecological networks or equitable green-space provision reflect the cumulative and often nonlinear effects of vertical and horizontal instrument combinations. Any attempt to spatialise policy therefore needs to encode not only the location and geometry of specific rules, but also the level of government that owns them, their temporal sequence, and their interaction with broader fiscal and regulatory environments.

Policy Spatial Footprint (PSF) as a Bridge Between Policy Text and Spatial Exposure

Despite the richness of work on instruments, spatial dimensions and multi-level governance, most empirical studies still rely on relatively crude representations of “policy exposure”. A large body of research approximates exposure to transit projects, environmental regulations or amenities using Euclidean buffers (e.g., within 500 m of a new rail station) or administrative units (e.g., within a municipality explicitly targeted by a programme). Built-environment and health studies have progressively adopted more sophisticated network-based and space-time accessibility measures (Kwan, 1998; Fang & Yu, 2010; Song et al., 2018; Labib et al., 2021), but even here exposure is usually defined relative to physical objects (roads, parks, pollution sources) rather than to the legal or fiscal coverage of policy in-

struments themselves. In parallel, environmental-planning research has developed detailed spatial models of ecosystem services, ecological functional zones and nature-based solutions (Deng et al., 2023; Fistola, 2023; Qiu et al., 2022; Lai & Zoppi, 2024), yet these typically map desired outcomes or biophysical processes rather than the normative reach of specific ordinances, regulations or subsidies.

The Policy Spatial Footprint (PSF) framework proposed by Xie et al. (2025) directly addresses this gap by treating planning and regulatory texts as sources of spatially explicit information. Starting from policy documents—such as station-area development plans, transit-oriented zoning codes and land-value capture ordinances—PSF extracts the clauses that define where, when and how a rule applies. These clauses are translated into georeferenced geometries (points, lines and polygons) that represent the legal coverage of the policy, including inclusion and exclusion areas and multiple intensity levels (e.g., primary vs. secondary impact zones). Each geometry is time-stamped to distinguish between policy announcement, legal enactment and practical implementation, thereby enabling event-study and difference-in-differences designs that account for anticipation effects and implementation lags.

A key innovation of PSF is the explicit use of network-time exposure rather than Euclidean distance. By projecting parcel locations onto multimodal transport networks and calculating shortest travel times to PSF geometries, the framework recognises that accessibility gains and regulatory constraints propagate along actual mobility paths rather than radiating isotropically in space (Xie et al., 2025). This approach builds conceptually on time-geographic accessibility measures (Kwan, 1998) and more recent network-based exposure studies (Song et al., 2018; Labib et al., 2021) but links them directly to the legal geometry of policy instruments. In the Yangtze River Delta case, Xie et al. show that land-value impacts of high-speed rail and associated station-area policies are more sharply defined in network-time space than in straight-line buffers, and that failing to use network-time exposure can lead to underestimation or misidentification of policy effects.

Compared with traditional spatial planning evaluations, PSF offers three further advantages. First, it is explicitly auditable: because PSF geometries are derived from specific textual clauses, they can be traced back to their legal sources and revised when regulations change, aligning with calls in the policy-instrument literature for more transparent and reflexive instrument design (Howlett, 2018; Capano & Howlett, 2020). Second, PSF is compositional: footprints from different instruments (e.g., density bonuses, environmental buffers, affordable-housing requirements) can be overlaid to reveal zones of instrument synergy or conflict, making the notion of a “policy mix” spatially explicit (Restemeyer & Witte, 2024; Kirsop-Taylor et al., 2022). Third, PSF is model-agnostic: once policy exposure has been

encoded in network-time space, it can be combined with hedonic pricing models, spatial difference-in-differences, or agent-based simulations, facilitating comparative evaluation across diverse empirical designs.

At the same time, the PSF approach also has limitations that are important for a balanced conceptualisation. Constructing footprints is labour-intensive and requires close collaboration between legal, planning and GIS expertise; ambiguities in policy texts can translate into spatial uncertainty that must be explicitly documented and, where possible, quantified. Moreover, PSF has so far been applied primarily to land-use and transport policies in data-rich settings; extending it to domains such as environmental health, ecosystem services or social policy may require new conventions for coding diffuse or relational obligations (e.g., city-wide emission caps, region-wide ecosystem restoration targets). These challenges, however, are not unique to PSF: they mirror broader difficulties in instrument design and multi-level governance, where overlapping competences and vague mandates are common (OECD, 2017; Nadin et al., 2021; Dorado-Rubín et al., 2025). In this sense, PSF should be viewed not as a fully resolved solution but as a bridge concept that operationalises the links between policy instruments, spatial dimensions of impact, and causal inference tools—providing a common language through which heterogeneous studies on policy–space interactions can be compared and synthesised.

EMPIRICAL EVIDENCE BY POLICY DOMAIN

Across the final sample of 142 articles, most studies focus on land-use regulation, transport and environmental or climate policies, with comparatively fewer contributions on social and health policies or rural and agricultural development. **Table 2** summarises the distribution of studies by policy domain, spatial scale and world region, indicating a marked concentration in higher-income countries and metropolitan regions. **Table 3** cross-tabulates policy domains, spatial exposure metrics and identification strategies, highlighting, for example, the predominance of simple distance- or administrative-unit-based exposure in earlier work and the growing use of network-time and PSF-based measures in more recent studies. These patterns provide the empirical context for the more detailed domain-specific discussions that follow.

Land-Use Regulation, Zoning and Spatial Governance

Land-use intensity, green transition and carbon outcomes

Empirical research increasingly shows that regulation of land-use intensity and functional zoning is closely tied to urban carbon outcomes. Studies using meta-

Table 2 | Distribution of included studies by policy domain, spatial scale and world region

Dimension	Category	Number of studies (n)	Share of sample (%)
Policy domain	Land-use and spatial planning	48	33.8
Policy domain	Transport and infrastructure	36	25.4
Policy domain	Environmental and climate policy	30	21.1
Policy domain	Social and health policy	18	12.7
Policy domain	Rural and peri-urban development	10	7.0
	Subtotal	142	100.0
Spatial scale	Parcel or neighbourhood	40	28.2
Spatial scale	City or municipal	55	38.7
Spatial scale	Metropolitan or regional	30	21.1
Spatial scale	National or multi-level	17	12.0
	Subtotal	142	100.0
World region	Europe	52	36.6
World region	North America	38	26.8
World region	East Asia	27	19.0
World region	Other high-income regions	9	6.3
World region	Low- and middle-income regions	16	11.3
	Subtotal	142	100.0

Table 3 | Cross-tabulation of spatial exposure metrics and methodological approaches

Spatial exposure metric	Descriptive spatial analysis	Spatial econometric models	Quasi-experimental designs	Simulation models	Mixed / qualitative GIS
Binary inclusion in zoning or PSF polygons	•••	•••	••	•	••
Euclidean buffers or distance-decay functions around infrastructure or facilities	•••	•••	••	•••	•
Administrative-unit assignment (e.g. census tracts, municipalities)	••	•••	•••	•	••
Network-based travel time to PSF boundaries, stations or facilities	••	••	•••	••	•
Composite eligibility indices constructed from multiple criteria	•	••	••	•••	•••

Note: Cells indicate the relative frequency of combinations in the sample (••• = common; •• = occasional; • = rare; – = not observed).

analytic and multi-city designs demonstrate that higher densities, mixed land uses and transit-supportive built forms reduce vehicle-kilometres travelled and associated emissions, though effects are heterogeneous across contexts (Ewing & Cervero, 2010; Glaeser & Kahn, 2010). Within this broader literature, recent work has turned to explicitly policy-based measures of intensity, such as floor area ratio (FAR) caps, bonus FAR schemes and land-use conversion quotas, to examine how regulatory choices shape both operational and transport-related carbon emissions. For example, Wang and colleagues use panel data for Northeast China to show that cities combining compact, transit-oriented spatial plans with strict controls on low-density expansion achieve significantly lower per-capita emissions than similarly industrialised cities without such planning coherence (Wang et al., 2025). Their difference-in-differences models suggest that up-zoning around transit nodes can reduce transport emissions while only modestly increasing building-related emissions, leading to

net carbon benefits when design standards include energy-efficiency requirements.

Another line of work focuses on FAR incentives and development rights as levers for low-carbon urban form. Cheshmehzangi and Dawodu (2021) combine urban form indicators with energy-model scenarios to show that shifting allowable FAR from peripheral to inner-city zones can lower aggregate energy use and emissions, provided that green building codes are enforced in higher-intensity areas. Similarly, transport-oriented spatial planning in Taipei, analysed through a scenario-based spatial model, indicates that concentrating growth within planned high-intensity corridors can cut transport CO₂ emissions by more than 10% relative to business-as-usual, even when overall population and economic activity continue to rise (Wang et al., 2018). These studies collectively suggest that the carbon effects of intensity regulation are highly path-dependent: up-zoning can either lock in high-carbon forms or support green transition, depending on whether regulations

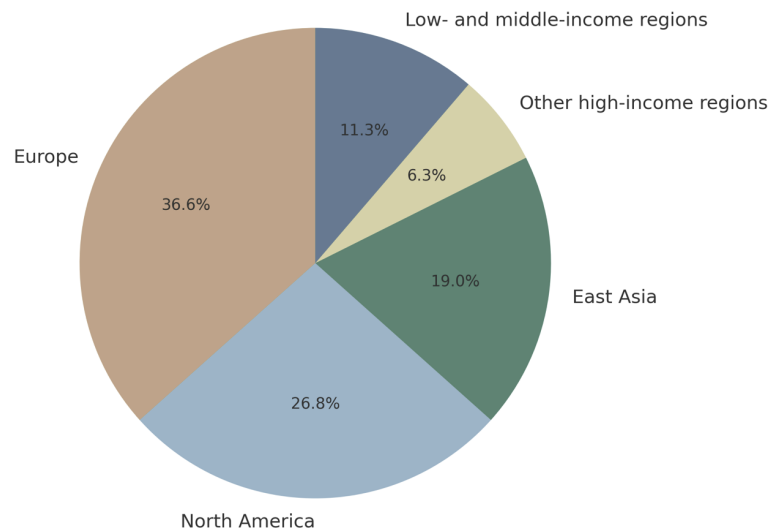


Figure 2 | Regional distribution of included studies by world region

are coordinated with transit investment, building-energy standards and green-space provision.

Beyond aggregate emissions, recent work links land-use intensity policy to spatial patterns of carbon sources and sinks. Remote-sensing based analyses show that enforced minimum plot ratios in central areas often correlate with the loss of small urban green patches, which in turn diminishes local cooling and carbon-sequestration capacity, while strict protection of vegetated areas in peri-urban zones can partially compensate at larger scales (Wang et al., 2025; Xiong & Yao, 2025). These findings underline that FAR and zoning ordinances should be evaluated not only for their influence on trip generation and building energy, but also for their impact on the spatial balance between built surfaces and urban ecosystems.

Urban spatial growth, containment and green belts

Urban containment instruments—urban growth boundaries, green belts, ecological red lines and permanent agricultural protection zones—constitute a second major cluster of spatial policies. Early evaluations of Swiss and other European containment policies found that statutory growth boundaries could substantially reduce leapfrog development and increase infill, though sometimes at the cost of higher land prices and densification pressures inside the boundary (Gennaio et al., 2009). Subsequent comparative work shows that the effectiveness of such instruments depends less on the mere existence of a boundary than on its legal rigidity, enforcement capacity and coordination with transport and housing policies (Kirby et al., 2023).

Recent studies emphasise the multi-functional character of containment instruments. Xiong and Yao (2025) analyse the spatial evolution of metropolitan green belts, showing that belts designated primarily for recreational and landscape purposes may be progressively

encroached upon unless backed by strong land-use controls and clear compensation mechanisms for landowners. Where green belts are explicitly integrated into regional ecological networks and climate-adaptation strategies, they appear more resilient against incremental erosion and more effective at steering growth towards transit-served corridors. At the same time, evidence from Chinese and European cases indicates that too rigid containment can displace growth into more distant, poorly served jurisdictions, generating longer commuting distances and increasing regional transport emissions (Gennaio et al., 2009; Kirby et al., 2023).

Methodologically, most evaluations of containment policies rely on spatial metrics of built-up expansion (e.g., edge-expansion indices, leapfrog development rates, infill ratios), combined with land-price or accessibility indicators. More recent work incorporates scenario-based modelling to simulate how alternative boundary locations and accompanying housing policies might alter both land-use efficiency and carbon outcomes (Wang et al., 2018; Xiong & Yao, 2025). However, very few studies explicitly encode the legal geometry and timing of containment provisions—as opposed to simply treating the observed built-up edge as a proxy—leaving scope for more policy-explicit approaches such as PSF to distinguish between *de jure* and *de facto* boundaries.

Informality, compliance and implementation gaps

Empirical evidence from the Global South underscores that the spatial impact of land-use regulation is mediated by enforcement capacity and informality. Goytia et al. (2023) exploit parcel-level data from Buenos Aires and find that stringent zoning regulations, when weakly enforced, can unintentionally push low-income households into informal settlements beyond the regulated urban perimeter. Their results suggest that formal

regulatory strictness, absent affordable pathways to compliance, may expand rather than shrink informal urban footprints. Complementary studies in African and Asian cities show that informal residential expansion often follows infrastructure corridors and environmentally sensitive areas where formal planning is absent or unenforced, leading to fragmented land-use patterns and ecosystem degradation (Hailu, 2024; Ahmad et al., 2025).

Research using high-resolution imagery and street-scale surveys highlights that planned and unplanned settlements can evolve markedly different spatial morphologies despite similar locational advantages. Mottelson (2023) compares the internal form of planned and unplanned neighbourhoods in Maputo, Mozambique, demonstrating that planned areas have more regular street grids and clearer plot demarcation but not necessarily higher effective densities. In contrast, unplanned zones exhibit organic street patterns and irregular plots, yet may achieve similar or greater residential densities through incremental vertical expansion. These findings challenge simple narratives equating informal with low density, and show that the main spatial efficiency gap often lies in limited access connectivity, lack of public green space and exposure to environmental hazards rather than density per se.

From a policy perspective, recent studies stress the importance of implementation trajectories. Ahmad et al. (2025) analyse Karachi as a “planned city with unplanned land use” and show how decades of ad hoc regularisation and tolerance of informal subdivisions have produced a highly fragmented mosaic of land uses only partially aligned with official land-use plans. Hailu (2024) documents similar dynamics in Addis Ababa, where informal settlements at the urban edge convert agricultural and ecological land without adequate provision of services, undermining ecosystem services and exacerbating spatial inequalities. Together, this literature suggests that the spatial outcomes of land-use regulation result from the interplay of formal instruments, enforcement practices, political economy and everyday coping strategies, and that quantitative evaluation must therefore consider both on-paper regulations and their de facto relaxation, evasion or reinterpretation.

Land value capitalization and PSF: evidence from the Yangtze River Delta

The link between regulatory policies and land values has long been documented in hedonic and quasi-experimental studies, which show that zoning changes, environmental regulations and transport investments are capitalised into land and housing prices (Ewing & Cervero, 2010; Glaeser & Kahn, 2010; Li et al., 2022; Suzuki et al., 2013). However, most empirical work continues to proxy policy exposure using simple distance-to-infrastructure measures, coarse administrative dummies or post-hoc land-use classifications, which ob-

scure the spatial and temporal specificities of policy design and implementation. The Policy Spatial Footprint (PSF) framework proposed by Xie et al. (2025) represents a significant methodological advance by explicitly mapping the spatial geometry, timing and strength of multiple policy instruments and linking them to parcel-level land transactions.

Using approximately 1.10 million land-transaction records from five Yangtze River Delta cities between 2012 and 2024, Xie et al. (2025) construct PSFs for 64 policies spanning planning regulations, transport investments and industrial-land programmes. Policy clauses are parsed and translated into spatial footprints with attributes capturing effective dates, applicable land-use types, intensity thresholds and explicit inclusion or exclusion zones. Network-time buffers based on combined rail-road travel times are then used to define exposure, replacing the conventional Euclidean distance. This enables a staggered multi-period difference-in-differences design in which parcels entering or leaving PSF exposure zones at different times serve as treated and control observations. The results show that direct exposure to PSFs associated with major transport and zoning changes leads to statistically significant increases in land prices over several years, with the magnitude and duration of effects depending on local market depth and pre-existing regulatory “positions” (stringency and credibility of past plans). Spillover effects into adjacent but formally non-covered zones decay rapidly with additional network-travel time, indicating that accessibility and policy credibility interact to shape the spatial decay of capitalisation effects.

When compared with studies that rely on generic zoning or distance measures, PSF-based analysis provides several advantages. First, it allows disentangling overlapping policy effects where multiple regulations co-exist in space and time, such as the combination of TOD zoning, industrial-land restrictions and environmental buffers (Li et al., 2022; Wang et al., 2025). Second, the explicit mapping of exclusions and carve-outs clarifies why some parcels close to infrastructure do not experience expected price gains, thereby reducing omitted-policy bias. Third, the network-time exposure metric aligns more closely with actual accessibility and service coverage than straight-line buffers, especially in polycentric regions with complex transport networks. Finally, because PSFs are constructed from auditable legal documents and planning maps, they can be updated and extended across sectors (e.g., environmental, social, fiscal policies), creating a common spatial layer for integrated policy evaluation and comparative studies across cities.

Transport and Mobility Policies With Spatial Effects

Transport and mobility policies modify spatial structure both directly, by reshaping accessibility patterns, and indirectly, by influencing location decisions of

households and firms. A large body of empirical work shows that fixed-guideway transit investments and transit-oriented development (TOD) policies are associated with higher densities, greater land-use mixing and reduced car dependence in station areas, although distributive outcomes vary (Ewing & Cervero, 2010; Bertolini, 1999). Cervero and Kang (2011), using a hedonic price model for Seoul, find that bus rapid transit (BRT) corridors with supportive land-use controls generate substantial land-value uplift within walking distance of stations, especially where zoning allows higher intensity and mixed uses. Their results highlight that without explicit land-use reforms, the spatial leverage of transport investments is limited.

Recent studies systematically integrate land value capture (LVC) into evaluations of transport policy. Li et al. (2022) propose a systemic model linking transport investment, accessibility gains and LVC instruments such as betterment levies, joint development and development rights sales, arguing that the spatial distribution of accessibility benefits should guide the design of LVC schemes. Their empirical application shows that station areas with clear, enforceable up-zoning and public land ownership enable more robust LVC than areas where land-use regulations are fragmented. Lin and Wei (2025) examine TOD in metropolitan China and find that rail-served suburbs with strong TOD zoning and inclusionary housing requirements have higher densities and lower car mode shares than similar suburbs without such policies, but may also exhibit rising land prices and socio-spatial sorting.

From a methods perspective, most transport–land-use studies still measure policy exposure via fixed radius buffers around stations or corridors. Network-based accessibility metrics are gaining ground, yet explicit encoding of policy provisions (such as minimum densities, parking maximums or pedestrian-priority zones) remains rare. The PSF approach demonstrates how transport-related policy clauses—such as service coverage guarantees, intermodal transfer requirements or station-area zoning overlays—can be translated into spatial footprints and network-time catchments. By doing so, it becomes possible to estimate not only average station-area effects, but also distributional outcomes across different PSF overlays, such as zones with transit priority plus affordable-housing requirements, versus zones with transit improvements but no land-use reforms (Xie et al., 2025; Li et al., 2022). This integration of transport policy, spatial regulation and land economics is crucial for designing mobility strategies that are both financially and socially sustainable.

Environmental and climate policies in spatial planning

Environmental and climate policies increasingly operate through spatially explicit instruments such as ecological protection zones, low-emission districts, flood risk overlays and carbon-neutral spatial plans. Empirical

studies from Europe and East Asia show that integrating climate-mitigation and adaptation objectives into spatial planning can shift development away from high-risk or carbon-intensive locations and foster more compact, transit-supportive patterns (Wang et al., 2018; Menoni & Ferreira, 2025). For instance, Menoni and Ferreira (2025) compare local land-use plans before and after the introduction of national climate-planning guidelines, noting a rise in the designation of flood-resilient zones, compact growth areas and green infrastructure corridors, with measurable changes in subsequent development applications.

In China, Qiu and Xu (2022) review municipal practices and identify several pathways by which climate mitigation is incorporated into urban master plans, including industrial restructuring, transit-oriented intensification and green-space systems designed for both recreation and carbon sequestration. Yet they also point out implementation gaps, as many plans lack clear legal status or enforcement mechanisms. At the micro-scale, studies using building-energy and urban-climate models suggest that environmental regulations targeting building envelopes, street-canyon geometry and urban greenery can produce localised cooling and emissions reductions, but the cumulative effect depends on how these measures are spatially distributed relative to population and activity density (Cheshmehzangi & Dawodu, 2021; Wang et al., 2025).

The PSF logic is readily extendable to environmental and climate policies. Ecological red lines, low-emission zones and hazard-based building restrictions are all defined by legal texts and maps that can be converted into spatial footprints with attributes describing restriction types, enforcement dates and allowable uses. While few studies have fully operationalised such PSFs, early work on ecological zoning and carbon-neutral district planning shows that explicitly mapping protected and regulated areas can clarify trade-offs between development rights and environmental objectives, and can support compensation schemes for landowners in restricted zones (Guo et al., 2023; Hou et al., 2025; Tesfay et al., 2025). Incorporating these environmental PSFs into land-value and development models would allow more systematic evaluation of how climate and biodiversity policies are capitalised into land markets and how they reshape the spatial distribution of risk and opportunity.

Social, Health and Post-Pandemic Policies With Spatial Implications

Social and health policies increasingly operate through spatial rules on service catchments, accessibility standards and quality-of-life indicators. Evidence from public-health and urban-planning research shows that proximity to green spaces, walkable street networks and local services is associated with lower mortality, better mental health and higher levels of physical activity (Twohig-Bennett & Jones, 2018). Despite these

findings, many cities still rely on coarse administrative boundaries or simple distance thresholds when defining school catchments, health-service areas or “healthy-city” targets, without fully considering the underlying transport networks and barriers.

The COVID-19 pandemic further highlighted the spatial dimension of social and health policies. While this review focuses primarily on 2020–2025, much of the empirical evidence builds on pre-pandemic work on active travel and greenspace exposure. Studies in European and Asian cities show that neighbourhoods with pre-existing walkability, mixed land uses and accessible green spaces better supported physical activity and social distancing during lockdowns, while car-dependent peripheral areas suffered more severe mobility constraints and mental-health burdens (Ewing & Cervero, 2010; Twohig-Bennett & Jones, 2018). These patterns have motivated proposals for “15-minute city” and “complete neighbourhood” policies, which essentially encode spatial standards for access to daily needs into planning regulations.

From a policy-evaluation perspective, most social and health-related spatial policies are still assessed using proxies: for example, counting facilities within fixed radii or within administrative units. There is substantial scope to apply PSF-style mapping to encode detailed policy clauses—such as maximum walking distances to primary schools, required provision of parks per capita, or eligibility zones for housing vouchers—into spatial footprints aligned with network-time metrics. Doing so would allow more precise estimation of how changes in these policy parameters affect spatial inequalities in access, and how they are capitalised into land and housing prices, particularly in post-pandemic reconfigurations of urban life.

Rural and Peri-Urban Policies and Spatial Restructuring

Finally, rural and peri-urban policies have profound spatial effects, particularly in fast-urbanising regions. Cultivated-land protection policies, rural-revitalisation programmes and land-consolidation schemes reshape settlement patterns, agricultural land-use and ecological networks at the rural–urban interface. Guo et al. (2023) analyse cultivated-land conservation policies in China and show that strict protection quotas can reduce the rate of farmland conversion overall, but may also encourage more intensive land use and construction in unprotected pockets, leading to fragmented landscapes. Hou et al. (2025) examine farmland-protection spatial governance in peri-urban China and find that the spatial configuration of protection zones—continuous belts versus scattered patches—significantly affects both farmland fragmentation and the feasibility of compact urban expansion.

Farmland-consolidation and land-readjustment programmes illustrate how rural policies can function as spatial instruments. Tesfay et al. (2025) use micro-data

from Ethiopia to show that consolidation policies can reduce plot fragmentation and improve agricultural productivity, but may simultaneously increase income inequality if better-connected households capture disproportionate gains. In many countries, rural-revitalisation strategies also promote the redevelopment of village centres into compact service hubs and tourism destinations, often combined with the relocation of scattered hamlets. Yet systematic spatial evaluations of these policies remain scarce, especially regarding their long-term effects on ecosystem services and mobility patterns.

The PSF framework offers a way to bring rural and peri-urban policies into the same analytical space as urban regulations. Protection zones, consolidation areas, rural-revitalisation pilot villages and collective-construction land pilot zones are all defined by legal documents that can be mapped as spatial footprints with attributes describing tenure, permitted uses and policy duration (Guo et al., 2023; Hou et al., 2025; Tesfay et al., 2025). Linking these rural PSFs to parcel-level land-use and value data would allow researchers to examine whether rural and peri-urban policies complement or contradict urban containment, TOD and environmental regulations, and how the combined policy mix shapes long-term spatial restructuring across the urban–rural continuum.

METHODOLOGICAL TRENDS IN ASSESSING POLICY–SPACE IMPACTS

The past two decades have seen a rapid convergence between spatial econometrics, quasi-experimental designs, simulation modelling, and data-rich GIS and remote sensing, fundamentally reshaping how policy–space relationships are identified and quantified. Classical spatial regression tools have been refined to better accommodate policy spillovers and multi-scalar dependence, while advances in causal inference have sharpened concerns about treatment definition, interference, and dynamic selection. At the same time, land-use–transport and environmental models have become more behaviourally explicit, and remotely sensed and street-level data now allow fine-grained observation of spatial outcomes. Against this background, the Policy Spatial Footprint (PSF) framework proposed by Xie et al. (2024) is emblematic of a new generation of methods that treat policies themselves as auditable spatio-temporal data objects, closing the long-standing gap between legal text, spatial exposure, and causal identification.

Spatial Econometrics and Quasi-Experimental Designs

Spatial econometrics provides the original toolbox for modelling spatial dependence in policy evaluations. Anselin’s (1988) monograph laid the foundations for

formal spatial lag, spatial error, and spatial Durbin models, emphasising how regional outcomes are jointly determined by their own covariates and the outcomes or characteristics of neighbouring units. Subsequent contributions by LeSage and Pace (2009) and Elhorst (2014) developed comprehensive treatments of spatial panel models, including fixed-effects specifications suitable for policy interventions that unfold over time. Methodological work on the spatial Durbin model and common-factor tests has clarified when spillovers operate primarily through dependent variables or covariates, with important implications for interpreting policy diffusion and cross-jurisdictional externalities (Mur & Angulo, 2006). Comparative simulations further show that misspecification of spatial weights or functional forms can lead to biased impact estimates, highlighting the need for carefully designed neighbourhood structures in regional policy analysis (Rüttenauer, 2019).

These technical developments have been accompanied by critical reflections on the “value add” of spatial econometrics for policy evaluation. Gibbons and Overman (2012) argue that many applications fail to connect spatial dependence parameters to substantive economic mechanisms, risking “mostly pointless” spatial embellishments when identification remains weak. Corrado and Fingleton (2012) similarly call for stronger theoretical grounding, insisting that spatial specifications should reflect behavioural processes and institutional context rather than merely detecting residual autocorrelation. In the context of land-use regulation, transport infrastructure, and environmental zoning, these debates translate into a demand for treatment variables that reflect the actual geometry and timing of policy exposure. If zoning overlays, corridor plans or ecological red lines are crudely proxied by radial buffers or administrative dummies, then even sophisticated spatial regressions remain vulnerable to misclassification and omitted mechanism bias.

In parallel, quasi-experimental designs have become the dominant standard for causal claims in applied policy evaluation. Difference-in-differences (DiD) and related designs provide transparent estimators of average treatment effects under parallel trend assumptions, extending earlier instrumental-variable traditions emphasised by Angrist and Pischke (2009). Synthetic control methods allow credible counterfactual trajectories for treated units, especially in small-N, staggered-adoption settings typical of institutional or planning reforms (Abadie, Diamond, & Hainmueller, 2010; Abadie, 2021). Recent advances explicitly address heterogeneous treatment timing and effects: Callaway and Sant’Anna (2021) propose group-time average treatment effects for multi-period DiD designs, while Sun and Abraham (2021) show that conventional two-way fixed-effects event-study estimators can be severely biased when effects vary across cohorts. De Chaisemartin and D’Haultfoeuille (2020) further demonstrate that two-way fixed-effects estimators can produce weighted averages

with negative weights under heterogeneity, motivating alternative estimators that preserve causal interpretability. Athey and Imbens (2022) formalise these concerns in a design-based framework and advocate estimators that explicitly reflect the assignment process and timing of policy adoption.

When these causal tools are combined with explicitly spatial outcomes—such as property prices, land-use change, or exposure to infrastructure—the key methodological bottleneck shifts to the definition of “treatment” and “control” in space. Spatial spillovers violate the stable unit treatment value assumption, as policies implemented in one jurisdiction may affect neighbouring units through migration, investment, and network effects. Spatial econometric models can partially address such interference by modeling lagged outcomes and covariates (Elhorst, 2014; Mur & Angulo, 2006), but they do not in themselves solve the problem of assigning exposure status. In many empirical studies, treatment is defined by simple Euclidean distance thresholds from a policy boundary or facility, or by coarse administrative membership. This creates sensitivity of DiD and event-study estimates to arbitrary buffer choices and ignores the network-time structure of accessibility. The emerging PSF approach directly targets this gap by translating detailed legal and planning texts into spatio-temporal treatment indicators that can be interfaced with staggered-adoption DiD and spatial panels, thereby aligning econometric design with the actual geometry and timing of policy implementation (Xie et al., 2024).

Land-Use, Transport and Environmental Modelling

A second major methodological strand concerns ex-ante simulation of policy impacts through land-use–transport interaction (LUTI) and environmental models. Wegener (2014) provides a comprehensive review of LUTI models that couple transport networks, location choice, and land-use change, tracing their evolution from early aggregate gravity-based systems to disaggregate and activity-based formulations. Acheampong and Silva (2015) synthesise more recent LUTI applications and highlight how they are increasingly used to test planning scenarios, such as transit-oriented development (TOD), congestion pricing, and growth boundaries, under varying behavioural and policy assumptions. In these models, spatial policy interventions are usually encoded as changes in zoning capacity, transport costs, or development constraints, which in turn drive simulated locational responses.

Multi-agent and agent-based approaches provide finer representations of decision making and heterogeneous actors. Crooks, Patel, and Wise (2014) discuss how multi-agent systems can represent residents, firms, and planners with distinct objectives and information sets in urban planning scenarios, allowing exploration of complex feedbacks between regulations, market dynamics, and built form. Parker and Filatova (2008) pro-

pose a conceptual design for bilateral agent-based land markets with heterogeneous agents, in which prices, development patterns, and land-use change emerge from decentralised bargaining rather than imposed equilibrium conditions. Wahyudi, Liu, and Corcoran (2019) extend this logic to developing-country contexts, simulating how heterogeneous private developers generate divergent urban land configurations under different policy constraints. Dai et al. (2020) review agent-based models of land systems and outline key design issues, including representation of planning rules, enforcement regimes, and environmental externalities. At the same time, Grimm et al. (2006) argue for standardised protocols (ODD) to improve the transparency and reproducibility of agent-based and individual-based models, which is particularly important when they are used to inform real-world policy debates.

Despite their sophistication, LUTI and agent-based models often treat policies as scenario parameters rather than as objects derived from actual legal and regulatory texts. For example, a greenbelt may be represented as a simple radial constraint, and a TOD policy as a density bonus within an arbitrary distance of a station (Acheampong & Silva, 2015; Wegener, 2014). Few models explicitly encode the multi-layered nature of real-world policy packages—where floor-area ratios, building height limits, parking standards, and inclusionary zoning requirements interact—and even fewer tie these representations to verifiable policy documents. As a result, while simulation models are powerful for exploring “what-if” trajectories and system dynamics, their policy levers are often stylised and difficult to align with the exact boundaries, exemptions, and phasing of enacted regulations. PSF-type methods can provide a bridge by offering empirically derived, geometry-rich representations of existing policy regimes that can be imported as model inputs, reducing the gap between scenario design and legal reality.

GIS, Remote Sensing and Big Data Analytics

Advances in GIS and remote sensing have dramatically improved the measurement of spatial outcomes, thereby strengthening the evaluation side of policy-space research. Seto, Fragkias, Güneralp, and Reilly (2011) conduct a meta-analysis of global urban land expansion and document systematic variation in growth rates by region, income level, and governance context, using consistent remote sensing products to harmonise land-cover change across hundreds of cities. Building on this, Seto, Güneralp, and Hutyra (2012) generate global forecasts of urban expansion to 2030 and quantify direct impacts on biodiversity and carbon pools, illustrating how large-scale land-change data can be overlaid with ecological layers to evaluate future planning risks. Bren d'Amour et al. (2017) similarly combine global urban expansion projections with high-resolution cropland maps to estimate the potential loss of prime agricultural land, underlining the importance of integrat-

ing land-use dynamics into food-security and climate policies. More recently, Gao et al. (2021) compare the spatiotemporal trajectories of global population growth and built-up land expansion, revealing mismatches that inform debates on urban form and infrastructure efficiency. Angel (2023) synthesises these strands to propose an “urbanization science” agenda, arguing that observed patterns of urban expansion can guide normative policy choices on containment, densification, and infrastructure investment.

At finer scales, street-level imagery and other “Big Geo-Data” sources are increasingly used to characterise neighbourhood form and environmental quality. Li et al. (2015) develop a modified green-view index based on Google Street View to measure street-level greenery, providing an accessible indicator for urban design and health studies. Similar pipelines have been adapted to estimate building heights, façade transparency, and pedestrian-scale enclosure, feeding into assessments of walkability and micro-climate. Remotely sensed products with high spatial and temporal resolution are also being mobilised for policy monitoring: Whitcraft, Becker-Reshef, and Killough (2015) evaluate the revisit capabilities of current and planned optical satellite missions for global agricultural monitoring, while Lancheros et al. (2018) assess the Copernicus system’s ability to support polar region monitoring, both explicitly framed around observational requirements for policy and sustainable development. These developments are part of a broader “Big Data (R)evolution” in geography, which Pérez and colleagues (2024) describe as simultaneously expanding the empirical scope of spatial analysis and posing new challenges of data integration, governance, and ethics.

However, the overwhelming focus of GIS, remote sensing, and big-data work has been on measuring outcomes and exposures—such as built-up land, vegetation, population density, or pollution—rather than on spatialising the policies that shape those outcomes. Land-use plans, zoning ordinances, and sectoral regulations are often represented in empirical work only indirectly, for example through treatment indicators defined by arbitrary buffers around infrastructure or administrative boundaries (Seto et al., 2012; Angel, 2023). This asymmetry means that highly detailed spatial outcome data are frequently paired with coarse or ad hoc policy proxies, limiting the interpretability of causal results and complicating meta-analysis across studies. The PSF framework can be seen as a response to this imbalance, proposing to treat policy instruments themselves as spatial datasets that can be versioned, audited, and combined with the rich observational layers produced by modern GIS and remote sensing.

Policy Quantification, PSF and Network-Time Exposure

Quantifying the content of policy texts has a long history in political science and policy studies, but only

recently has it become central to spatial policy evaluation. Early text-as-data methods such as Wordscores and related scaling models aimed to recover latent policy positions from party manifestos and legislative speeches (Laver, Benoit, & Garry, 2003; Slapin & Proksch, 2008). Grimmer and Stewart (2013) survey a wide range of automated content-analysis techniques and emphasise both their promise and pitfalls for drawing inferences from large corpora of political texts. Lucas et al. (2015) demonstrate how supervised and unsupervised machine-learning methods can be used to classify documents, detect topics, and extract covariates for comparative politics, while warning that measurement error and construct validity remain major concerns. In the climate and environmental domain, Geese, Ganseforth, and Kern (2024) apply text-as-data tools to systematically measure the content and ambition of climate policies across countries, illustrating how large textual corpora can be converted into structured indicators for subsequent statistical analysis. Sewerin et al. (2023) go further by introducing the POLIANNA dataset, in which policy documents are manually annotated along multiple design dimensions to support the training and validation of automated classifiers.

These approaches, however, primarily generate **scores** rather than **shapes**: they quantify what policies say, but not where they apply. For spatial planning and land-use governance, the missing link is a systematic way to translate textual provisions—such as zoning categories, overlay districts, buffer requirements, and exemption clauses—into geometries on the ground. Xie et al. (2024) address this gap by proposing the Policy Spatial Footprint (PSF) framework, which defines policies as spatio-temporal objects derived directly from legal and planning documents. Their four-stage workflow begins with the collection and semantic parsing of policy texts, identifying relevant clauses and associating them with spatial referents (e.g., specific corridors, station areas, ecological zones). In the second stage, these referents are converted into vector geometries—points, lines, and polygons—using cadastral, transport, and administrative base layers, while explicit exclusion rules (such as de-listed parcels or overlapping regimes) are encoded as negative geometries. Third, each footprint is assigned time stamps corresponding to announcement, legal effect, and implementation phases, and categorised into intensity levels reflecting regulatory stringency or fiscal generosity. Finally, exposure metrics are computed for parcels or other spatial units, including Euclidean buffers, network-time isochrones, and multi-policy overlap indicators, with explicit treatment of uncertainty arising from ambiguous or incomplete clauses.

A defining feature of PSF is its use of network-time rather than simple distance as the primary measure of policy exposure. In their Yangtze River Delta application, Xie et al. (2024) compute shortest travel times along combined road–rail networks from each land-

transaction parcel to the nearest PSF geometries, arguing that accessibility to policy-defined zones, rather than proximity per se, drives the capitalisation of regulatory and infrastructure benefits into land prices. This network-time exposure is then embedded in a staggered-adoption DiD framework that distinguishes direct footprint effects from diffuse spillovers, while spatial panel specifications allow for cross-parcel dependence. Conceptually, this design brings together the strengths of spatial econometrics and modern DiD: treatment is defined at the level of observable legal geometry and network-time reach, while interference is modelled through both explicit PSF overlaps and residual spatial lags.

Relative to conventional policy quantification, PSF offers several advantages. First, the processing chain from legal text to spatial exposure is fully auditable and reproducible: each policy's geometry can be visualised, checked against original maps or statutory descriptions, and updated as amendments occur. Second, policy exposure becomes a continuous, multi-dimensional construct rather than a binary buffer membership, facilitating nuanced analyses of threshold effects, decay functions, and interactions between overlapping instruments—for example, where density bonuses, infrastructure subsidies, and environmental constraints co-exist (Xie et al., 2024). Third, by anchoring treatment variables in policy texts rather than outcomes, PSF reduces endogeneity concerns arising from ad hoc buffer choice or reverse-engineered treatment definitions. The approach is also inherently scalable: new policy domains (e.g., health, education, or climate resilience) can be incorporated by adding further semantic categories and geometry-construction rules, and aspects of the workflow can be automated using the text-as-data and annotation techniques developed in the broader policy-measurement literature (Grimmer & Stewart, 2013; Sewerin et al., 2023).

At the same time, PSF raises practical and methodological challenges. Constructing high-quality policy footprints requires access to complete legislative and planning archives, including historical versions, as well as substantial domain expertise to interpret cross-referenced clauses and implicit spatial references. The GIS work needed to reconcile legal descriptions with real-world geometries—such as resolving ambiguities in corridor widths or station-area radii—can be resource-intensive, particularly when extended to multiple jurisdictions. Moreover, as PSF datasets become more complex, researchers must carefully manage multicollinearity between overlapping policies and ensure that network-time metrics do not simply proxy for broader urban hierarchy or market thickness. Addressing these issues will likely require closer integration of PSF workflows with both automated text-as-data pipelines and principled causal-inference designs, including sensitivity analyses that explicitly test alternative exposure definitions and lag structures.

Comparative and Cross-Case Frameworks

Finally, methodological advances in policy–space research increasingly emphasise comparative and cross-case designs, seeking to move beyond single-city case studies towards generalisable insights. Comparative LUTI and simulation studies already use shared model structures to explore how different metropolitan areas respond to identical policy shocks, yet they often rely on locally tailored representations of zoning and governance (Wegener, 2014; Acheampong & Silva, 2015). Global urban-expansion analyses similarly adopt common land-change datasets and metrics, but treat planning and regulation only as background context or coarse categorical variables (Seto et al., 2011, 2012; Bren d'Amour et al., 2017; Angel, 2023). Without harmonised measures of policy exposure, it remains difficult to compare, for example, the effect of urban containment in one country with transit-oriented zoning in another, even when outcomes are measured with similar satellite or cadastral data.

PSF-type frameworks open the possibility of genuinely cross-national and cross-institutional comparisons of spatial policy effects. If different cities and countries adopt a shared protocol for translating planning statutes, infrastructure plans, and environmental regulations into spatio-temporal footprints, researchers can apply common causal designs—such as staggered-adoption DiD with network-time exposure—to evaluate heterogeneous treatment effects across institutional settings (Athey & Imbens, 2022; Callaway & Sant'Anna, 2021; Xie et al., 2024). Such a standard would also facilitate meta-analysis: instead of comparing studies that use different buffer distances, administrative units, or ad hoc zoning categories, analysts could pool PSF-based exposure metrics and estimate how the effectiveness of similar policy instruments varies with governance capacity, market structure, or urban morphology. In this sense, PSF does not compete with spatial econometrics, simulation modelling, or remote-sensing analytics; rather, it provides a common, geometry-rich policy layer that can be combined with these methods to produce more transparent, comparable, and policy-relevant evidence on how public interventions reshape space.

CROSS-CUTTING THEMES AND KNOWLEDGE GAPS

Sectoral Fragmentation Versus Integrated Spatial Governance

Across most planning systems, land-use regulation, transport investment, environmental protection, housing, and public health are still largely organised as separate policy sectors with their own legal bases, budgeting streams, and professional communities. Comparative work on land-use governance shows that responsi-

bilities for zoning, infrastructure, and environmental regulation are often distributed across several ministries and levels of government, with only weak mechanisms for coordination (Krawchenko & Tomaney, 2023; Nadin et al., 2021). Studies of policy integration similarly argue that, although “joined-up” government has become a ubiquitous slogan, substantive integration of objectives, instruments, and implementation routines remains the exception rather than the rule (Howlett et al., 2017; Trein et al., 2023). Mechanism-focused analyses find that fragmentation is reproduced by sectoral mandates, path-dependent routines, and institutionalised veto points, which make it difficult to align, for instance, climate mitigation with agricultural, housing, and transport policies at the same time (Biesbroek & Candel, 2020; Eckhardt et al., 2020).

Recent systematic reviews of land-use governance confirm that social norms, market dynamics, and policy interventions interact in complex ways, and that the institutional architecture of the state often fails to provide a coherent spatial strategy that joins these forces (Dingkuhn et al., 2025). While national climate strategies and net-zero roadmaps increasingly acknowledge the importance of compact, transit-oriented urban forms, implementation frequently remains siloed at the level of sectoral ministries or projects (Lwasa et al., 2022; Seto et al., 2012). Global evidence on urban expansion and densification suggests that without integrated governance, containment policies, greenbelts, transit investments, and housing programmes can easily pull urban development in different directions, reproducing low-density growth and car dependence (Angel et al., 2021; Seto et al., 2011).

In this context, digitalisation has been presented as a possible remedy for fragmentation by enabling shared spatial data infrastructures and integrated decision-support tools. However, reviews of urban digital twins show that governance ambitions often outstrip institutional capacity: many projects remain confined to specific sectors (energy, mobility, flood risk) and rarely engage with statutory planning processes or cross-sectoral prioritisation (Azadi et al., 2025; Deng et al., 2021; Deren et al., 2021). Technical work on nationally connected digital twins and geospatial infrastructures stresses the need for common data models and governance arrangements if spatial data are to support integrated policy packages rather than isolated pilots (D'Hauwers et al., 2021; Ellul et al., 2024). Yet even in advanced cases of dynamic digital twins for city development, questions remain about how far these tools actually reshape organisational routines and sectoral power relations (Batty, 2018, 2024; Ferré-Bigorra & Neumann, 2022; Hämäläinen et al., 2021; Campos et al., 2025; Sánchez-Vaquerizo et al., 2025). The emerging policy spatial footprint (PSF) approach adds a different but complementary perspective: by encoding multiple sectoral policies in a common spatial framework, PSF can reveal overlaps, gaps, and conflicts in

the actual geographic reach of land-use, transport, environmental, and fiscal instruments, thus making fragmentation empirically visible rather than treating it as an abstract governance problem (Xie et al., 2025; Dingkuhn et al., 2025).

Temporal Dynamics, Path Dependency and Lock-in

A second cross-cutting theme concerns the temporal structure of policy–space interactions. Classic work on carbon lock-in argued that energy and transport systems become entrenched through mutually reinforcing technological, institutional, and behavioural feedbacks, making them resistant to change even when low-carbon alternatives are available (Unruh, 2000). More recent reviews extend the lock-in lens to the built environment, arguing that urban form, housing stocks, and infrastructure networks create long-lived path dependencies that constrain future mitigation and adaptation options (Buzási & Csizovszky, 2023; Seto et al., 2012). Meta-analyses of urban expansion show that once low-density, leapfrog patterns are established, subsequent densification policies must contend with entrenched property rights, infrastructure layouts, and expectations of car-based mobility (Seto et al., 2011; Angel et al., 2021).

Despite this recognition, empirical policy evaluations still tend to focus on short-term effects of single instruments. Many studies examine land price changes in the years immediately following a zoning reform, transit project, or greenbelt designation, without tracing how multiple waves of policy adjustments and market responses accumulate over one or two decades (Eckhardt et al., 2020; Krawchenko & Tomaney, 2023). Climate policy assessments underline that achieving deep decarbonisation requires sequences of interventions that purposefully shift infrastructures, technologies, and spatial practices over time, yet robust empirical evidence on such sequences remains limited (Lwasa et al., 2022; Seto et al., 2021; Biesbroek & Candel, 2020).

The PSF approach provides an example of how temporal dynamics can be incorporated more systematically. In the Yangtze River Delta case, the PSF database captures the announcement, legal enactment, and operationalisation of 64 land-use, transport, and industrial policies over 2012–2024, and links each temporal layer to observed changes in land prices within and around the affected areas (Xie et al., 2025). By constructing staggered treatment cohorts for successive policy waves and estimating dynamic effects over multiple post-treatment years, the study traces how capitalization effects build up, taper off, or reverse, and how they interact with broader market cycles. Similar dynamic designs are beginning to appear in access-based hedonic models of transport project benefits (Wang & Levinson, 2023) and in evaluations of bus rapid transit (BRT) corridors that consider both initial and delayed

land development responses (Cervero & Kang, 2011; Mehmood et al., 2024). However, such temporally explicit analyses are still rare. Existing evidence therefore provides only partial insight into how early policy choices constrain or enable later interventions, and how lock-ins can be deliberately dismantled.

Policy–Space–Economy Coupling and Unintended Consequences

A third cross-cutting theme is the tight but often under-analysed coupling between policy, spatial structure, and economic outcomes. Land-use and transport policies alter accessibility patterns, development rights, and risk profiles, which in turn shape land values, investment decisions, and fiscal capacities. Hedonic and accessibility-based models show that improvements in network connectivity and regulatory relaxations tend to be capitalised into higher land prices, with magnitudes varying by market thickness, baseline accessibility, and complementary policies (Wang & Levinson, 2023; Cervero & Kang, 2011). Work on land value capture (LVC) highlights that capturing part of this uplift through taxes, fees, or joint development can help finance infrastructure but also risks regressive impacts if not carefully designed (Botticini & Auzins, 2022; Echevarría et al., 2025). Reviews of land-use governance underline that the distribution of development rights and fiscal instruments is central to explaining why some jurisdictions see speculative booms, spatial exclusion, or fiscal crises after major infrastructure projects, while others achieve more balanced development (Dingkuhn et al., 2025; Krawchenko & Tomaney, 2023).

The PSF contribution is to create a more explicit bridge between policy text, spatial exposure, and economic outcomes. By mapping regulatory and infrastructure policies into auditable geometries with time stamps and intensity levels, PSF allows researchers to define treatment not simply as “within x km of a station” but as “within the legally defined area of a particular policy at a particular time” (Xie et al., 2025). In the Yangtze River Delta application, network-time exposure measures distinguish parcels that are inside a policy footprint and closely connected via road–rail networks from those that are spatially adjacent but poorly connected, revealing steep decay of capitalization effects in network-time rather than in Euclidean distance. This approach clarifies how specific combinations of zoning rules, infrastructure commitments, and industrial designations shape land price trajectories, instead of attributing all effects to a generic “transit impact.” Evidence from BRT corridors and associated land development confirms that land markets respond to both spatial design and the credibility of long-term service provision (Cervero & Kang, 2011; Mehmood et al., 2024). At the same time, digital twin experiments show that economic and land market impacts are rarely integrated into governance dashboards, which often focus on traffic flows or energy use (Batty, 2018, 2024; Azadi et al., 2025;

Hämäläinen et al., 2021). Overall, there is still limited causal evidence on unintended consequences such as speculative bubbles, displacement, or fiscal over-reliance on land revenues, even though conceptual work clearly identifies these risks.

Uneven Geography of Evidence

The existing body of work on policy–space interactions is marked by a pronounced geographical skew. Systematic reviews of land-use governance and climate policy integration find that most empirical studies focus on Europe, North America, and a small number of large Chinese cities, while evidence from small cities, secondary regions, and the Global South remains sparse (Dingkuhn et al., 2025; Eckhardt et al., 2020; Krawchenko & Tomaney, 2023). Meta-analyses of global urban expansion and densification identify strong regional contrasts in growth patterns but note that detailed policy histories are rarely available outside a limited set of cases, making it difficult to attribute observed trajectories to specific instruments or governance arrangements (Seto et al., 2011, 2012; Angel et al., 2021). Even in rapidly urbanising regions where infrastructure roll-out and land reform are proceeding at pace, empirical work often treats policy as a coarse dummy (e.g., “post-reform period”) rather than reconstructing the fine-grained spatial reach of different measures.

The digital governance literature exhibits a similar concentration. Systematic reviews of urban digital twins report that most documented projects are located in North America, Western Europe, China, and a few high-income Asian countries, with city-scale implementations often concentrated in capital regions or global hubs (Deng et al., 2021; Azadi et al., 2025). Case studies of smart-city digital twins from Helsinki, Shanghai, and other major cities push the methodological frontier but do little to illuminate how such tools might support governance in small municipalities with limited data and capacity (Deren et al., 2021; Hämäläinen et al., 2021; Campos et al., 2025; Sánchez-Vaquerizo et al., 2025). Work on nationally connected digital twin infrastructures further reinforces a focus on countries with strong geospatial agencies and substantial public investment in data infrastructures (D'Hauwers et al., 2021; Ellul et al., 2024; Abdelrahman et al., 2025). Against this backdrop, the PSF application to Chinese county-level cities is one of the few examples of a high-resolution, policy-explicit spatial dataset outside core OECD contexts (Xie et al., 2025). However, comparable PSF-style reconstructions for African, South Asian, Latin American, or Eastern European cities are still missing, which limits our ability to draw robust conclusions about how institutional variation shapes policy–space relationships globally.

Under-Researched Policy Instruments and Outcomes

Finally, there are notable gaps in the types of instruments and outcomes examined. Most empirical work still centres on land-use regulation, transport infrastructure, and, to a lesser extent, environmental zoning and hazard regulation (Dingkuhn et al., 2025; Nadin et al., 2021). By contrast, fiscal and tax instruments—such as land value taxation, tax increment financing, betterment levies, and impact fees—receive far less attention in spatially explicit evaluations, despite their centrality for funding infrastructure and shaping development incentives. Recent conceptual and empirical contributions on land value capture underline both the potential and the pitfalls of these instruments: while well-designed schemes can align private gains with public infrastructure costs, poorly designed ones may entrench inequalities or incentivise speculative up-zoning (Botticini & Auzins, 2022; Echevarría et al., 2025; Wang & Levinson, 2023). Yet most of this work either uses coarse spatial proxies for policy (for example, buffers around stations assumed to be subject to LVC) or focuses on financial and legal design without reconstructing the actual spatial reach of the instruments.

Digital and information-based tools represent another under-researched frontier. While digital twins, smart-city platforms, and open data portals are increasingly deployed with the stated aim of improving spatial governance, few studies systematically track how they alter decision-making, participation, or outcomes on the ground (Batty, 2018, 2024; Ferré-Bigorra & Neumann, 2022; Abdelrahman et al., 2025; Campos et al., 2025). Existing evaluations typically measure technical performance rather than policy change, leaving unanswered whether such tools reinforce existing sectoral silos or help to integrate policy mixes. Similarly, outcome variables remain skewed towards land prices, development densities, and carbon emissions, with far fewer studies examining distributional justice, public health, or subjective wellbeing as spatially structured outcomes (Lwasa et al., 2022; Buzási & Csizovszky, 2023). The PSF framework, by making policy exposure explicit and auditable, offers a platform for extending analyses beyond land markets to social and health indicators, but this potential has not yet been realised in empirical work (Xie et al., 2025; Krawchenko & Tomaney, 2023). Addressing these gaps will require closer collaboration between fiscal scholars, public health researchers, and spatial analysts, as well as investment in longitudinal, multi-sector datasets that link policy, space, and diverse outcomes in a comparable way.

TOWARDS AN INTEGRATED ANALYTICAL FRAMEWORK

A Policy–Space–Outcome Framework Anchored by PSF

An integrated analytical framework for policy–space interactions needs to connect three elements that are often studied in isolation: the formal design of policy instruments, the spatial structure of exposure and mediation, and the multidimensional outcomes that emerge over time. Comparative research on urban expansion, climate mitigation and land-use governance shows that spatial outcomes are driven by overlapping regulatory, infrastructural and fiscal choices, rather than by any single instrument (Seto et al., 2011, 2012, 2021; Angel et al., 2021; Dingkuhn et al., 2025; Eckhardt et al., 2020; Krawchenko & Tomaney, 2023; Nadin et al., 2021). The Policy Spatial Footprint (PSF) concept proposed by Xie et al. (2025) offers a way to anchor these elements in a single workflow by treating policy itself as an auditable spatio-temporal data object. In this framework, the inputs are legal and planning texts, which are parsed and converted into spatial footprints with attributes for timing and intensity; these footprints are then used to compute exposure metrics in network-time space, which feed into models of land, transport, environmental and social processes, and ultimately into environmental, economic, social and health outcomes.

On the input side, the PSF stage translates heterogeneous policies—zoning ordinances, infrastructure plans, ecological red lines, industrial designations and fiscal instruments—into a harmonised layer of geometries tagged with dates and intensity levels (Xie et al., 2025). This responds directly to the longstanding observation that spatial governance is fragmented across sectors and levels, with poorly aligned policy mixes for land, transport, environment and social provision (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Howlett et al., 2017; Krawchenko & Tomaney, 2023; Nadin et al., 2021; Trein et al., 2023). Instead of representing planning as a single boundary or dummy variable, PSF allows each instrument to be represented explicitly and combined into additive or conflicting packages. For example, a station area may simultaneously fall under transit-oriented up-zoning, flood-risk building restrictions and inclusionary housing requirements; each of these can be encoded as a separate footprint, with overlaps indicating where trade-offs and synergies must be analysed (Cervero & Kang, 2011; Menoni & Ferreira, 2025; Qiu & Xu, 2022; Wang S. et al., 2018; Wang Y. et al., 2025; Xiong & Yao, 2025).

The second layer of the framework concerns spatial exposure and mediation. Network-time accessibility is a central element here, because the benefits and burdens of policies are transmitted along transport and service networks rather than purely through straight-line distance (Angel et al., 2021; Ewing & Cervero, 2010;

Glaeser & Kahn, 2010; Wang & Levinson, 2023; Xie et al., 2025). PSF-based exposure metrics therefore measure how quickly parcels, neighbourhoods or villages can “reach” policy-defined areas, and vice versa, using multimodal travel-time surfaces derived from road–rail networks (Abdelrahman et al., 2025; Angel et al., 2021; Deren et al., 2021; Wang & Levinson, 2023). These exposure fields then interact with mediating subsystems: land and housing markets (Li et al., 2022; Suzuki et al., 2013; Xie et al., 2025), transport networks and mode choice (Bertolini, 1999; Cervero & Kang, 2011; Mehmood et al., 2024), environmental processes such as emissions and ecosystem services (Guo et al., 2023; Hou et al., 2025; Menoni & Ferreira, 2025; Seto et al., 2012; Twohig-Bennett & Jones, 2018), and social structures including informality, segregation and access to services (Ahmad et al., 2025; Goytia et al., 2023; Hailu, 2024; Lin & Wei, 2025; Mottelson, 2023; Tesfay et al., 2025).

The final layer captures outcomes and feedbacks. Environmental outcomes include direct impacts on land-cover change, carbon emissions and climate risk, which can be measured with remote sensing and environmental models (Angel et al., 2021; Buzási & Csizovszky, 2023; Guo et al., 2023; Hou et al., 2025; Seto et al., 2011, 2012, 2021; Wang S. et al., 2018; Wang Y. et al., 2025). Economic outcomes include land and housing price capitalisation, investment patterns and fiscal positions, which are shaped by both policy exposure and market conditions (Botticini & Auzins, 2022; Echevarría et al., 2025; Li et al., 2022; Suzuki et al., 2013; Wang & Levinson, 2023; Xie et al., 2025). Social outcomes encompass spatial inequality in access to jobs, education, health and green space, as well as the expansion or regularisation of informal settlements (Ahmad et al., 2025; Goytia et al., 2023; Hailu, 2024; Lin & Wei, 2025; Mottelson, 2023; Tesfay et al., 2025; Twohig-Bennett & Jones, 2018). Health outcomes are increasingly recognised as spatially mediated, reflecting exposure to pollution, heat, green space and active travel opportunities (Buzási & Csizovszky, 2023; Lwasa et al., 2022; Seto et al., 2021; Twohig-Bennett & Jones, 2018). The framework also recognises feedback loops: spatial outcomes affect future policy choices and market expectations, reinforcing or eroding carbon and spatial lock-in (Angel et al., 2021; Buzási & Csizovszky, 2023; Seto et al., 2012; Unruh, 2000).

In operational terms, the proposed policy–space–outcome framework can be seen as a modular architecture. PSF provides the input layer of policy footprints and exposure metrics. Spatial econometrics and quasi-experimental designs link these exposures to outcome data, while simulation models and digital twins can be placed in the mediation layer to explore dynamic scenarios (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; D’Hauwers et al., 2021; Ellul et al., 2024; Hämäläinen et al., 2021). Remote sensing, GIS and administrative microdata

populate the outcome layer with high-resolution indicators (Angel et al., 2021; Guo et al., 2023; Hou et al., 2025; Seto et al., 2011, 2012; Xie et al., 2025). Governance analyses of policy integration and land-use institutions provide the interpretive context, clarifying why similar policy mixes have different effects across jurisdictions (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Eckhardt et al., 2020; Howlett et al., 2017; Krawchenko & Tomaney, 2023; Nadin et al., 2021; Trein et al., 2023).

Application to Ex-Ante and Ex-Post Assessment

Anchoring evaluation in PSF also enables a clearer distinction and linkage between ex-ante and ex-post assessment. Ex-ante, planners and policymakers increasingly use scenario models to explore the implications of different spatial strategies for emissions, congestion, ecosystem services or housing affordability. Yet many land-use–transport and environmental models still encode policies in stylised ways, such as simple density changes, generic growth boundaries or uniform green-space targets (Angel et al., 2021; Ewing & Cervero, 2010; Menoni & Ferreira, 2025; Seto et al., 2012; Wang S. et al., 2018). Integrating PSF into these models would allow scenarios to be defined directly in terms of alternative policy footprints and timings: for example, comparing a compact transit-corridor PSF package with an edge-expansion package, holding demographic and macroeconomic assumptions constant (Bertolini, 1999; Guo et al., 2023; Hou et al., 2025; Qiu & Xu, 2022; Wang Y. et al., 2025; Xiong & Yao, 2025). The resulting forecasts of land-use change, emissions, and accessibility can then be attributed to specific policy configurations rather than to generic “smart growth” or “business-as-usual” labels.

Digital twins and related geospatial infrastructures provide a complementary ex-ante environment. Many city and national digital-twin initiatives already integrate 3D built-form representations, real-time traffic data and environmental sensors (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; Deren et al., 2021; Härmäläinen et al., 2021). Yet these platforms often lack explicit encodings of planning rules, fiscal instruments and sectoral regulations, limiting their value for testing governance options (Deng et al., 2021; D’Hauwers et al., 2021; Ellul et al., 2024; Ferré-Bigorra & Neumann, 2022; Sánchez-Vaquerizo et al., 2025). Embedding PSF layers into digital twins would allow users to visualise where and when different policies apply, test alternative footprints, and immediately see how they interact with predicted flows and risks, for example by overlaying alternative flood-risk building regulations with projected climate hazards and transport access (Eckhardt et al., 2020; Lwasa et al., 2022; Menoni & Ferreira, 2025; Seto et al., 2021).

Ex-post, PSF-based treatment definitions can be combined with econometric and quasi-experimental

designs to estimate realised impacts. Xie et al. (2025) show how staggered difference-in-differences models with network-time exposure and parcel fixed effects can identify the timing and magnitude of land price capitalisation for overlapping waves of zoning, infrastructure and industrial policies. Their approach can be generalised to other outcomes, such as built-up expansion, densification, mode share, emissions or health indicators (Angel et al., 2021; Buzási & Csizovszky, 2023; Guo et al., 2023; Hou et al., 2025; Seto et al., 2011, 2012; Twohig-Bennett & Jones, 2018). Accessible land-market models and LVC evaluations already provide templates for linking accessibility changes to price trajectories (Botticini & Auzins, 2022; Cervero & Kang, 2011; Echevarría et al., 2025; Li et al., 2022; Mehmood et al., 2024; Wang & Levinson, 2023), but in most cases the causal variable is a coarse distance buffer or project dummy. Replacing these proxies with PSF-based indicators can sharpen identification and reveal heterogeneity across policy packages.

Remote sensing and administrative microdata are equally central to ex-post analysis. Global urban-expansion datasets and high-resolution built-up maps can be used to observe land-cover and density changes in and around PSF footprints over time (Angel et al., 2021; Seto et al., 2011, 2012, 2021; Wang S. et al., 2018; Wang Y. et al., 2025). Parcel and address registers allow fine-grained tracking of development and tenure changes, while social registries and health records can provide outcome indicators for distributional and wellbeing analyses (Ahmad et al., 2025; Goytia et al., 2023; Hailu, 2024; Lin & Wei, 2025; Tesfay et al., 2025; Twohig-Bennett & Jones, 2018). When combined with PSF-based treatment, these datasets make it possible to test, for example, whether TOD and containment policies jointly produce compact, low-carbon and equitable outcomes, or whether they mainly deliver price gains near high-access areas alongside displacement into informal or peripheral zones. The same framework can quantify the extent to which climate and ecological regulations shift risk exposure or concentrate development in residual high-risk pockets (Buzási & Csizovszky, 2023; Eckhardt et al., 2020; Guo et al., 2023; Hou et al., 2025; Lwasa et al., 2022; Seto et al., 2021).

Implications for Policy Design and Spatial Planning Practice

The analytical framework outlined above has several implications for how policies and plans are written, negotiated and implemented. First, if PSF-style evaluation is to be possible, policy documents need to be drafted in ways that make spatial and temporal coverage unambiguous. Reviews of land-use governance and climate policy integration repeatedly point to vague formulations, overlapping jurisdictions and ambiguous exemptions as sources of implementation gaps and policy conflicts (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Eckhardt et al., 2020; Howlett et al., 2017; Kraw-

chenko & Tomaney, 2023; Nadin et al., 2021; Trein et al., 2023). From a PSF perspective, these ambiguities directly translate into uncertainty about footprint geometry and timing. Planners and legislators can therefore increase evaluability by specifying clear geographic boundaries (preferably tied to cadastral or network features), explicit activation and sunset dates, and transparent hierarchy rules for overlapping regulations.

Second, planning practice needs to shift from instrument-by-instrument design towards explicit policy-mix configuration in space. The evidence reviewed in earlier chapters shows that transport, land-use, environmental and fiscal instruments interact strongly, sometimes reinforcing and sometimes offsetting each other (Angel et al., 2021; Echevarría et al., 2025; Krawchenko & Tomaney, 2023; Li et al., 2022; Nadin et al., 2021; Wang & Levinson, 2023; Xie et al., 2025). PSF makes these interactions visible by revealing where TOD zoning coexists with strict parking minimums, where ecological buffers overlap with planned growth areas, or where industrial designations and residential up-zoning collide. This information can feed back into plan-making: planners can use PSF overlays in digital twins and GIS environments to identify conflict zones, test alternative package geometries, and adjust compensation and mitigation measures (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; Deren et al., 2021; Ellul et al., 2024; Hämäläinen et al., 2021; Sánchez-Vaquerizo et al., 2025).

Third, integrating network-time exposure and equity analysis into fiscal instruments is essential. LVC tools such as betterment levies, development charges and joint development are increasingly advocated to finance infrastructure, but their design often ignores the distribution of accessibility gains and burdens across different groups and places (Botticini & Auzins, 2022; Cervero & Kang, 2011; Echevarría et al., 2025; Li et al., 2022; Suzuki et al., 2013; Wang & Levinson, 2023). By combining PSF-based exposure metrics with land-price and socio-demographic data, planners can identify who benefits and who pays under different LVC schemes, and adjust parameters accordingly—for example, by calibrating rates to network-time gains or earmarking revenue for affordable housing in high-exposure zones (Ahmad et al., 2025; Goytia et al., 2023; Lin & Wei, 2025; Mehmood et al., 2024; Tesfay et al., 2025). Similar reasoning applies to climate and environmental regulations: PSF layers for heat-risk overlays, flood zones or air-pollution controls can be combined with health and income data to assess whether protective measures disproportionately favour already advantaged areas (Buzási & Csizovszky, 2023; Lwasa et al., 2022; Seto et al., 2021; Twohig-Bennett & Jones, 2018).

Finally, the framework suggests new roles for spatial planners and geospatial professionals in policy design. Instead of being consulted only after broad policy choices have been made, they can contribute to draft-

ing PSF-ready clauses, building and maintaining policy footprint repositories, and mediating between sectoral agencies with different objectives (Dingkuhn et al., 2025; Krawchenko & Tomaney, 2023; Nadin et al., 2021). Integrating PSF into urban digital twins and national spatial-data infrastructures can help move spatial planning from a largely static, document-centred practice towards a more iterative and evidence-based process, in which policy proposals are routinely stress-tested in space and time before adoption (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; D'Hauwers et al., 2021; Ellul et al., 2024; Ferré-Bigorra & Neumann, 2022; Sánchez-Vaquerizo et al., 2025).

FUTURE RESEARCH AGENDA

Advancing Causal and Multi-Scale Methods

Future research on policy–space interactions needs to move beyond single-scale, single-instrument evaluations towards designs that can credibly identify the effects of complex policy packages across multiple spatial and temporal scales. Existing work has demonstrated the value of quasi-experimental approaches such as difference-in-differences, event studies and access-based hedonic models in isolating the impacts of transport projects, zoning changes and growth boundaries, but these studies typically rely on coarse distance buffers or administrative boundaries to define treatment (Cervero & Kang, 2011; Echevarría et al., 2025; Kirby et al., 2023; Li et al., 2022; Mehmood et al., 2024; Wang & Levinson, 2023). Global analyses of urban expansion and densification similarly operate at city or metropolitan scales, leaving the micro-spatial pathways through which policy affects land markets, emissions and social outcomes only loosely specified (Angel et al., 2021; Seto et al., 2011, 2012, 2021; Wang S. et al., 2018; Wang Y. et al., 2025). There is therefore a clear need to integrate PSF-based treatment definitions with multi-scale spatial econometric models that explicitly represent parcel, neighbourhood, city and regional processes, and to exploit recent advances in staggered difference-in-differences and event-study estimators for heterogeneous and overlapping treatments.

The PSF application in the Yangtze River Delta provides a template for such work by combining detailed, policy-derived exposure metrics with dynamic panel models of land value capitalisation (Xie et al., 2025). Extending this approach to other outcomes and contexts would require careful consideration of spatial dependence, network spillovers and scale interactions. For example, future studies could use PSF-based treatment at parcel or grid level, while simultaneously modelling higher-level feedbacks in infrastructure provision or fiscal capacity using hierarchical or multilevel models (Abdelrahman et al., 2025; Campos et al., 2025; Dingkuhn et al., 2025; Krawchenko & Tomaney,

2023; Nadin et al., 2021). Integrating PSF with spatial Durbin or network autoregressive models would allow researchers to distinguish between direct effects within policy footprints and indirect effects transmitted through transport and development networks (Angel et al., 2021; Ewing & Cervero, 2010; Glaeser & Kahn, 2010; Wang & Levinson, 2023). Similarly, combining PSF with remote-sensing-based land-cover trajectories and dynamic climate-risk indicators could underpin event-study designs that capture both immediate and lagged responses of built-up expansion, emissions and exposure to hazards (Buzási & Csizovszky, 2023; Guo et al., 2023; Hou et al., 2025; Menoni & Ferreira, 2025; Seto et al., 2011, 2012, 2021).

Another methodological frontier lies in bridging causal inference with exploratory simulation. Land-use–transport and environmental models already incorporate detailed representations of behaviour and feedbacks but often rely on stylised scenarios rather than actual policy histories (Bertolini, 1999; Cheshmehzangi & Dawodu, 2021; Guo et al., 2023; Menoni & Ferreira, 2025; Suzuki et al., 2013; Wang S. et al., 2018). PSF can provide empirically grounded inputs for these models, enabling ex-post replication of historical policy sequences and ex-ante prototyping of alternative policy mixes. Future work could combine PSF-derived policy sequences with agent-based or cellular automata models to explore how different timing, intensity and spatial targeting of policies affect long-term urban form and lock-in, subject to empirical calibration using quasi-experimental estimates (Angel et al., 2021; Buzási & Csizovszky, 2023; Echevarría et al., 2025; Seto et al., 2012, 2021; Unruh, 2000). This would support a more iterative dialogue between theory, empirical identification and scenario analysis than is currently common in the literature.

Building Open Spatial Policy Datasets and PSF Repositories

A second priority is the systematic construction and sharing of open spatial policy datasets. At present, most PSF-style datasets are bespoke and confined to single projects or regions, limiting comparability and reuse (Dingkuhn et al., 2025; Eckhardt et al., 2020; Krawchenko & Tomaney, 2023; Xie et al., 2025). By contrast, there has been significant progress towards open, standardised datasets for land cover, urban expansion, emissions and exposure, which have enabled global meta-analyses of urbanisation and climate risk (Angel et al., 2021; Buzási & Csizovszky, 2023; Guo et al., 2023; Hou et al., 2025; Seto et al., 2011, 2012, 2021; Wang Y. et al., 2025). The asymmetry between rich outcome data and sparse, non-standard policy data hampers both replication and cross-city comparison. Future research agendas should therefore prioritise the development of PSF repositories that store ordinance texts, machine-readable clauses, geometry files, time stamps

and uncertainty annotations under open licences and with clear documentation.

Digital-twin and national geospatial infrastructure initiatives offer a natural institutional home for such repositories. Many current digital twins already integrate high-resolution 3D building models, transport networks and sensor data but lack explicit layers for planning rules and fiscal instruments (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; Deren et al., 2021; Hämäläinen et al., 2021; Sánchez-Vaquerizo et al., 2025). Embedding PSF repositories into these platforms would enable both analysts and practitioners to visualise policy coverage and to query the regulatory and fiscal status of any location. Nationally connected digital twins and spatial data infrastructures, as currently being piloted in several countries, could adopt common PSF schemas to facilitate cross-regional benchmarking and multi-level governance analysis (D'Hauwers et al., 2021; Ellul et al., 2024; Lwasa et al., 2022; Menoni & Ferreira, 2025).

Building such repositories will require methodological and institutional innovation. From a methodological standpoint, research is needed on semi-automated text parsing, ontology design for policy clauses, and reproducible pipelines linking legal sources to spatial geometries and version control (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Ferré-Bigorra & Neumann, 2022; Howlett et al., 2017; Trein et al., 2023). From an institutional standpoint, questions of data governance, confidentiality and political sensitivity must be addressed, particularly for fiscal instruments and socially contested policies (Botticini & Auzins, 2022; Echevarría et al., 2025; Goytia et al., 2023; Lin & Wei, 2025; Tesfay et al., 2025). Adopting FAIR (findable, accessible, interoperable, reusable) principles and interoperable licensing frameworks can help foster trust and reuse, while pilot PSF repositories in willing cities or regions can demonstrate feasibility and benefits. Over time, such efforts could support meta-analyses that compare policy packages and outcomes across hundreds of jurisdictions, thereby addressing the current geographical and sectoral biases in the evidence base (Angel et al., 2021; Dingkuhn et al., 2025; Krawchenko & Tomaney, 2023; Seto et al., 2011, 2012, 2021).

Deepening Comparative Governance Studies

A third avenue for future research concerns comparative governance. Existing conceptual frameworks emphasise that land-use and spatial planning systems vary widely in their allocation of powers, fiscal capacities and enforcement mechanisms, which shapes the feasible “policy space” for local governments (Krawchenko & Tomaney, 2023; Nadin et al., 2021; Trein et al., 2023). Empirical work on climate policy integration and land-use governance similarly shows that coordination problems, path dependencies and sectoral veto points differ across centralised and decentralised regimes, but these analyses rarely link institutional vari-

ation to fine-grained spatial outcomes (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Eckhardt et al., 2020; Lwasa et al., 2022; Seto et al., 2021). Applying PSF in different governance contexts would create a basis for systematically comparing how similar policy instruments are deployed spatially and how their impacts on land markets, emissions and equity differ.

For example, comparative PSF studies could analyse how transit-oriented development, growth boundaries and greenbelts are defined and enforced in metropolitan regions under varying degrees of planning autonomy and fiscal dependence, building on existing work on transport-oriented development, growth boundaries and resilience (Angel et al., 2021; Bertolini, 1999; Cheshmehzangi & Dawodu, 2021; Kirby et al., 2023; Lin & Wei, 2025; Suzuki et al., 2013). Similarly, cross-national PSF analyses of land value capture schemes and development charges could examine how policy footprints, network-time exposure and capitalisation patterns differ between, for example, North American, European and Asian metropolitan regions (Botticini & Auzins, 2022; Echevarría et al., 2025; Li et al., 2022; Wang & Levinson, 2023; Xie et al., 2025). In decentralised systems, PSF could help to trace the proliferation of local zoning overlays and fiscal incentives, shedding light on inter-jurisdictional competition and regional spatial inequalities (Ahmad et al., 2025; Goytia et al., 2023; Hailu, 2024; Tesfay et al., 2025).

Such comparative work would also benefit from the integration of qualitative governance analysis with quantitative PSF datasets. Case studies of policy design, negotiation and implementation can help interpret why similar footprints arise under different institutional constraints, or why formally similar policies are applied in very different places (Dingkuhn et al., 2025; Krawchenko & Tomaney, 2023; Menoni & Ferreira, 2025; Nadin et al., 2021; Qiu & Xu, 2022; Trein et al., 2023). Conversely, PSF maps can guide qualitative inquiry by revealing unexpected patterns of overlap, gaps or exemptions that merit closer investigation. Over time, this dialogue between governance research and PSF-based spatial analysis could yield a richer understanding of how formal rules, informal practices and market forces jointly shape policy–space–outcome relations.

Integrating Resilience, Justice and Digitalisation

Finally, future research should integrate urban resilience, spatial justice and digitalisation into a unified policy–space research agenda. Studies of carbon and spatial lock-in stress that resilience depends on both the flexibility of physical infrastructures and the adaptability of institutional arrangements, yet few empirical evaluations explicitly measure how policy-induced changes in spatial structure affect exposure and vulnerability of different groups (Buzási & Csizovszky, 2023; Lwasa et al., 2022; Menoni & Ferreira, 2025; Seto et al., 2021; Unruh, 2000). At the same time, growing liter-

atures on informality, land regularisation and peri-urban transformation show that zoning and infrastructure policies frequently produce or reinforce socio-spatial inequalities, including the expansion of informal settlements in residual or risk-prone spaces (Ahmad et al., 2025; Goytia et al., 2023; Hailu, 2024; Mottelson, 2023; Tesfay et al., 2025). PSF, combined with network-time exposure metrics and socio-demographic data, could provide a framework for systematically measuring which groups are included or excluded from the benefits and burdens of policy packages, and how these distributions evolve over time.

Digitalisation adds another layer of complexity and opportunity. Urban digital twins and smart-city platforms promise to provide real-time situational awareness and decision support, but empirical reviews highlight substantial gaps between these ambitions and actual governance practices (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; Deng et al., 2021; Deren et al., 2021; Hämäläinen et al., 2021; Sánchez-Vaquerizo et al., 2025). Few implementations incorporate explicit justice or resilience metrics, and even fewer embed policy footprints in ways that allow users to understand the spatial distribution of regulatory and fiscal regimes. Future research should therefore explore how PSF layers can be integrated into digital twins to enable interactive analysis of resilience and justice—for example, by overlaying policy footprints with flood-risk maps, accessibility surfaces and indicators of deprivation or health vulnerability (Guo et al., 2023; Hou et al., 2025; Lin & Wei, 2025; Twohig-Bennett & Jones, 2018).

A justice-oriented PSF research agenda would also examine how policies governing digital infrastructures themselves—such as broadband roll-out, sensor deployment and data governance—shape spatial inequalities in access to digital services and data-driven governance (Campos et al., 2025; Ferré-Bigorra & Neumann, 2022; Sánchez-Vaquerizo et al., 2025). Encoding such policies as PSFs would allow analysts to measure which neighbourhoods are included in digital initiatives and how this interacts with existing inequalities in physical infrastructure and services. Ultimately, integrating resilience, justice and digitalisation within a PSF-anchored framework can support the design of policy packages that are not only efficient and low-carbon but also socially inclusive and robust to shocks.

CONCLUSIONS

This review has argued that understanding how policies shape space—and how spatial structures in turn mediate environmental, economic, social and health outcomes—requires an explicit representation of policy as a spatial and temporal object. Traditional approaches to policy evaluation in urban and regional studies have relied heavily on distance buffers, administrative

units and stylised scenarios to approximate policy exposure, which obscures the complexity of overlapping instruments and institutional arrangements (Angel et al., 2021; Cervero & Kang, 2011; Echevarría et al., 2025; Kirby et al., 2023; Li et al., 2022; Wang & Levinson, 2023). By contrast, the Policy Spatial Footprint framework formalised by Xie et al. (2025) represents a qualitative shift: it treats policy clauses as the primary data source, translates them into auditable geometries with time stamps and intensity levels, and computes network-time exposure measures that can be directly linked to observed trajectories in land prices, urban form, emissions and social outcomes.

The evidence reviewed across land-use, transport, environmental and social policy domains shows that spatial outcomes emerge from complex policy mixes, mediated by land and housing markets, transport networks, environmental processes and social structures (Ahmad et al., 2025; Angel et al., 2021; Buzási & Csizovszky, 2023; Dingkuhn et al., 2025; Goytia et al., 2023; Guo et al., 2023; Hou et al., 2025; Lwasa et al., 2022; Menoni & Ferreira, 2025; Nadin et al., 2021; Qiu & Xu, 2022; Seto et al., 2011, 2012, 2021; Tesfay et al., 2025). The PSF case from the Yangtze River Delta demonstrates how a multi-policy, multi-period dataset can be used to identify direct and spillover effects of overlapping zoning, infrastructure and industrial policies on land value capitalisation in network-time space (Xie et al., 2025). Similar principles can be extended to study emissions, risk exposure, accessibility and well-being, particularly when combined with advances in spatial econometrics, quasi-experimental designs, remote sensing and digital twins (Abdelrahman et al., 2025; Azadi et al., 2025; Batty, 2018, 2024; Campos et al., 2025; Deren et al., 2021; Ewing & Cervero, 2010; Guo et al., 2023; Hou et al., 2025; Sánchez-Vaquerizo et al., 2025).

At the same time, the review has highlighted significant gaps. Geographically, the evidence base is heavily skewed towards large cities in Europe, North America and China, with limited PSF-style work in small cities, peri-urban regions and the Global South (Ahmad et al., 2025; Dingkuhn et al., 2025; Goytia et al., 2023; Hailu, 2024; Mottelson, 2023; Tesfay et al., 2025). Sectorally, fiscal and tax instruments, digital-governance policies and health-related regulations remain under-researched from a spatial perspective, despite their centrality for financing infrastructure, managing risk and delivering equitable services (Botticini & Auzins, 2022; Echevarría et al., 2025; Lin & Wei, 2025; Twohig-Bennett & Jones, 2018; Wang & Levinson, 2023). Methodologically, there is a need for multi-scale, dynamic designs that integrate PSF with hierarchical models, simulation and digital twins, and for open PSF repositories that enable replication and comparative research (Abdelrahman et al., 2025; Campos et al., 2025; D'Hauwers et al., 2021; El-lul et al., 2024; Ferré-Bigorra & Neumann, 2022; Trein et al., 2023).

Overall, PSF should not be seen as a standalone technique but as a central component of a broader policy–space–outcome framework. Its main contribution is to align policy semantics, spatial networks and causal identification in a way that is transparent, auditable and extensible across contexts. Realising this potential will require closer collaboration between legal scholars, planners, economists, data scientists and communities, as well as institutional reforms that encourage clear, PSF-ready policy drafting and open sharing of spatial policy data (Biesbroek & Candel, 2020; Dingkuhn et al., 2025; Howlett et al., 2017; Krawchenko & Tomaney, 2023; Nadin et al., 2021; Qiu & Xu, 2022; Trein et al., 2023). The work of Xie et al. (2025) marks an important step in this direction, but much remains to be done to generalise PSF to other regions, policy domains and outcome dimensions. Advancing this agenda offers a promising route towards more rigorous, transparent and just evaluations of how policies shape the spaces in which people live, work and adapt to a changing climate.

References

1. Abadie, A., Diamond, A., & Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American Statistical Association*, 105(490), 493–505. <https://doi.org/10.1198/jasa.2009.ap08746>
2. Abdelrahman, M. M., Haddad, A., Zhou, Y., Lyu, H., & Ghaffarianhoseini, A. (2025). What is a digital twin anyway? Deriving the definition for the built environment from over 15,000 scientific publications. *Building and Environment*, 241, Article 112748. <https://doi.org/10.1016/j.buildenv.2025.112748>
3. Ahmad, N., Khan, S., & Ali, R. (2025). Unplanned land use in a planned city: A systematic analysis of Karachi's land use pattern. *Land*, 14(11), Article 2248. <https://doi.org/10.3390/land14112248>
4. Angel, S., Blei, A. M., Parent, J., Lamson-Hall, P., Sánchez, N. G., & Civco, D. L. (2021). Densify and expand: A global analysis of recent urban expansion. *Sustainability*, 13(7), Article 3835. <https://doi.org/10.3390/su13073835>
5. Angrist, J. D., & Pischke, J.-S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton University Press. <https://doi.org/10.1515/9781400829828>
6. Anselin, L. (1988). *Spatial econometrics: Methods and models*. Kluwer Academic. <https://doi.org/10.1007/978-94-015-7799-1>
7. Azadi, R., Amado, M. P., & Tan, W. (2025). What have urban digital twins contributed to urban planning and decision making? A systematic literature review and research agenda. *Smart Cities*, 8(1), Article 32. <https://doi.org/10.3390/smartcities8010032>
8. Bali, A. S., Howlett, M., Lewis, J. M., & Ramesh, M. (2021). Procedural policy tools in theory and practice. *Policy and Society*, 40(3), 295–311. <https://doi.org/10.1080/14494035.2021.1965379>
9. Banikoi, H., Assembe-Mvondo, S., & Judor, B. (2024). Embedding spatial planning in contemporary multi-level governance: Evidence from Sub-Saharan Africa. *Land Use Policy*, 133, Article 107324. <https://doi.org/10.1016/j.landusepol.2023.107324>
10. Batty, M. (2018). Digital twins. *Environment and Planning B: Urban Analytics and City Science*, 45(5), 817–820. <https://doi.org/10.1177/2399808318796416>
11. Batty, M. (2024). Digital twins in city planning. *Nature Computational Science*, 4(3), 192–199. <https://doi.org/10.1038/>

- s43588-024-00606-7
12. Bemelmans-Videc, M.-L., Rist, R. C., & Vedung, E. (Eds.). (2017). Carrots, sticks, and sermons: Policy instruments and their evaluation. Routledge. <https://doi.org/10.4324/9781315081748>
 13. Berrang-Ford, L., Ford, J. D., & Paterson, J. (2015). Are we adapting to climate change? Global environmental change and systematic reviews. *Regional Environmental Change*, 15(5), 755–769. <https://doi.org/10.1007/s10113-014-0708-7>
 14. Bertolini, L. (1999). Spatial development patterns and public transport: The application of an analytical model in Western European cities. *Journal of Transport Geography*, 7(4), 199–211. [https://doi.org/10.1016/S0966-6923\(99\)00013-6](https://doi.org/10.1016/S0966-6923(99)00013-6)
 15. Biesbroek, R., & Candel, J. J. L. (2020). Mechanisms for policy (dis)integration: Explaining food and climate change adaptation policy in the Netherlands. *Policy Sciences*, 53(1), 61–84. <https://doi.org/10.1007/s11077-019-09354-2>
 16. Botticini, F., & Auzins, A. (2022). Land use efficiency and value capture. *Encyclopedia*, 2(4), 1943–1958. <https://doi.org/10.3390/encyclopedia2040134>
 17. Buzási, A., & Csizovszky, A. (2023). Urban sustainability and resilience: What the literature tells us about “lock-ins”? *Ambio*, 52(1), 240–255. <https://doi.org/10.1007/s13280-022-01817-w>
 18. Callaway, B., & Sant’Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, 225(2), 200–230. <https://doi.org/10.1016/j.jeconom.2020.12.001>
 19. Campos, V. B. G., Consoli, S., de Almeida, R. L., & Pinho, P. (2025). Digital twins for urban governance: General desires and governance needs. *Urban Planning*, 10(3), 229–241. <https://doi.org/10.17645/up.v10i3.7437>
 20. Capano, G., & Howlett, M. (2020). The knowns and unknowns of policy instrument analysis: Policy tools and the current research agenda on policy mixes. *SAGE Open*, 10(1), 1–13. <https://doi.org/10.1177/2158244019900568>
 21. Cejudo, G. M., & Trein, P. (2023). Pathways to policy integration: A subsystem approach. *Policy Sciences*, 56(1), 9–27. <https://doi.org/10.1007/s11077-022-09483-1>
 22. Cervero, R., & Kang, C. D. (2011). Bus rapid transit impacts on land uses and land values in Seoul, Korea. *Transport Policy*, 18(1), 102–116. <https://doi.org/10.1016/j.tranpol.2010.06.005>
 23. Cervero, R., & Murakami, J. (2009). Rail and property development in Hong Kong: Experiences and extensions. *Urban Studies*, 46(10), 2019–2043. <https://doi.org/10.1177/0042098009339431>
 24. Chay, K. Y., & Greenstone, M. (2005). Does air quality matter? Evidence from the housing market. *Journal of Political Economy*, 113(2), 376–424. <https://doi.org/10.1086/427462>
 25. Cheshmehzangi, A., & Dawodu, A. (2021). Revisiting floor area ratio for sustainable urban form and energy planning. *Frontiers in Sustainable Cities*, 3, Article 687895. <https://doi.org/10.3389/frsc.2021.687895>
 26. Corgo, J., & Freitas, A. (2024). Nature-based solutions in spatial planning and policies for climate change adaptation: A systematic review. *Sustainable Cities and Society*, 110, Article 105656. <https://doi.org/10.1016/j.scs.2024.105656>
 27. Creutzig, F., Baiocchi, G., Bierkandt, R., Pichler, P.-P., & Seto, K. C. (2015). Global typology of urban energy use and greenhouse gas emissions. *Proceedings of the National Academy of Sciences*, 112(20), 6283–6288. <https://doi.org/10.1073/pnas.1417623112>
 28. Danylo, O., See, L., Schepaschenko, D., McCallum, I., Domian, D., & Fritz, S. (2019). Towards an integrated perspective on the spatial distribution of greenhouse gas emissions in cities by combining bottom-up and top-down approaches. *Mitigation and Adaptation Strategies for Global Change*, 24, 1271–1292. <https://doi.org/10.1007/s11027-019-9846-z>
 29. Deng, T., Zhang, K., & Chan, D. (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *Journal of Management Science and Engineering*, 6(2), 125–134. <https://doi.org/10.1016/j.jmse.2021.03.003>
 30. Deng, Z., Hu, J., Zhang, Q., Liu, Y., & Yu, Z. (2023). Incorporating ecosystem services into functional zoning for ecological conservation: A case study of the Shennongjia region. *Scientific Reports*, 13, Article 46182. <https://doi.org/10.1038/s41598-023-46182-0>
 31. Deren, L., Wenbing, Y., & Shaohua, W. (2021). Smart city based on digital twins. *Computational Urban Science*, 1(4), Article 23. <https://doi.org/10.1007/s43762-021-00005-y>
 32. D’Hauwers, R., Tosi, F., Bogart, S., et al. (2021). From an inside-in towards an outside-out urban digital twin: Business models and implementation challenges. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, VIII-4/W1, 25–32. <https://doi.org/10.5194/isprs-annals-VIII-4-W1-2021-25-2021>
 33. de Vries, S. (2021). The power of procedural policy tools at the local level: Australian local governments contributing to policy change for major projects. *Policy and Society*, 40(3), 414–432. <https://doi.org/10.1080/14494035.2021.1955471>
 34. Dingkuhn, E. L., Schlüter, M., Huber, R., et al. (2025). Land-use governance: The interplay of social, market, and policy drivers—A global systematic review. *Earth System Governance*, Article 100275. <https://doi.org/10.1016/j.esg.2025.100275>
 35. Dorado-Rubín, M., et al. (2025). Policy integration in urban policies as multi-level policy mixes. *Policy Sciences*. <https://doi.org/10.1007/s11077-024-09562-5>
 36. Dorado-Rubín, M. J., Guerrero-Mayo, M. J., & Navarro-Yáñez, C. J. (2025). Policy integration in urban policies as multi-level policy mixes. *Policy Sciences*, 58(1), 45–67. <https://doi.org/10.1007/s11077-024-09562-5>
 37. Dworczyk, C., Syrbe, R.-U., & Walz, U. (2021). Conceptualising the demand for ecosystem services. *One Ecosystem*, 6, Article e65966. <https://doi.org/10.3897/oneeco.6.e65966>
 38. Echevarría, J. C., Luby, M., & Monkkonen, P. (2025). Challenges to equitable and effective land value capture for public transport financing. *Urban Affairs Review*. Advance online publication. <https://doi.org/10.1177/10780874251323896>
 39. Eckhardt, F., Biesbroek, R., & Wamsler, C. (2020). Climate policy integration in the land-use sector: Achievements and future prospects. *Environmental Science & Policy*, 114, 583–592. <https://doi.org/10.1016/j.envsci.2020.08.020>
 40. Elhorst, J. P. (2014). *Spatial econometrics: From cross-sectional data to spatial panels*. Springer. <https://doi.org/10.1007/978-3-642-40340-8>
 41. Ellul, C., Stoter, J., Harrie, L., et al. (2024). Towards nationally connected digital twins: A geospatial perspective. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, X-4/W5-2024, 147–154. <https://doi.org/10.5194/isprs-annals-X4-W5-2024-147-2024>
 42. Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American Planning Association*, 76(3), 265–294. <https://doi.org/10.1080/01944361003766766>
 43. Fang, Z., & Yu, D. (2010). A space–time accessibility measure for transport planning. *Journal of Transport Geography*, 18(6), 947–956. <https://doi.org/10.1016/j.jtrangeo.2010.06.008>
 44. Ferré-Bigorra, J., & Neumann, A. (2022). A decision-driven data selection model for urban digital twin development. *Sustainable Cities and Society*, 87, Article 104167. <https://doi.org/10.1016/j.scs.2022.104167>
 45. Fistola, R. (2023). Ecosystem services for the city as a complex system: A methodological proposal. *Sustainability*, 15(23), Article 9318. <https://doi.org/10.3390/su15129318>
 46. Gennaio, M.-P., Hersperger, A. M., & Bürgi, M. (2009). Containing urban sprawl—Evaluating effectiveness of urban growth boundaries set by the Swiss Land Use Plan. *Land Use Policy*,

- 26(2), 224–232. <https://doi.org/10.1016/j.landusepol.2008.02.010>
47. Gibbons, S., & Overman, H. G. (2012). Mostly pointless spatial econometrics? *Journal of Regional Science*, 52(2), 172–191. <https://doi.org/10.1111/j.1467-9787.2012.00760.x>
 48. Glaeser, E. L., & Kahn, M. E. (2010). The greenness of cities: Carbon dioxide emissions and urban development. *Journal of Urban Economics*, 67(3), 404–418. <https://doi.org/10.1016/j.jue.2009.11.006>
 49. Goldstein, J. H., Caldarone, G., Duarte, T. K., Ennaanay, D., Hannahs, N., Mendoza, G., et al. (2012). Integrating ecosystem-service tradeoffs into land-use decisions. *Proceedings of the National Academy of Sciences*, 109(19), 7565–7570. <https://doi.org/10.1073/pnas.1117313109>
 50. Gong, W., Li, V. J., & Ng, M. K. (2021). Deciphering property development around high-speed railway stations through land value capture: Case studies in Shenzhen and Hong Kong. *Sustainability*, 13(22), Article 12605. <https://doi.org/10.3390/su132212605>
 51. Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, 26(2), 91–108. <https://doi.org/10.1111/j.1471-1842.2009.00848.x>
 52. Grêt-Regamey, A., Celio, E., Klein, T. M., & Hayek, U. W. (2017). Integrating ecosystem services into spatial planning—A spatial decision support system for case studies in Switzerland. *Landscape and Urban Planning*, 165, 175–186. <https://doi.org/10.1016/j.landurbplan.2016.03.005>
 53. Guo, R., Li, Z., & Yang, Y. (2023). Spatial effects of cultivated land conservation policies on rural land use in China. *Land*, 12(2), Article 491. <https://doi.org/10.3390/land12020491>
 54. Gurney, K. R., Mendoza, D. L., Zhou, Y., Fischer, M. L., de la Rue du Can, S., Geethakumar, S., & Miller, C. (2009). High resolution fossil fuel combustion CO₂ emission fluxes for the United States. *Environmental Science & Technology*, 43(14), 5535–5541. <https://doi.org/10.1021/es900806c>
 55. Hailu, T. (2024). Land use transformation driven by urban informal settlements and its impact on ecosystem services in Addis Ababa, Ethiopia. *Environmental Systems Research*, 13, Article 59. <https://doi.org/10.1186/s40068-024-00359-2>
 56. Hall, P., & Pain, K. (2006). The polycentric metropolis: Learning from mega-city regions in Europe. *Earthscan*. <https://doi.org/10.4324/9781849773911>
 57. Hämäläinen, J., Suomisto, J., & Penttinen, P. (2021). Urban development with dynamic digital twins in Helsinki City. *IET Smart Cities*, 3(3), 163–171. <https://doi.org/10.1049/smc2.12015>
 58. Hickmann, T., Stehle, F., Bromley-Trujillo, R., & Dijkstra, A. (2021). Locating cities and their governments in multi-level governance arrangements of climate change. *Politics and Governance*, 9(1), 96–106. <https://doi.org/10.17645/pag.v9i1.361>
 59. Hou, H., Yang, Y., Bi, Y., & Li, F. (2024). Socioeconomic inequalities in the distribution of urban green space in rapidly urbanizing China. *Land*, 13(5), Article 626. <https://doi.org/10.3390/land13050626>
 60. Hou, Y., Liu, Y., & Chen, Y. (2025). Spatial governance of farmland protection and farmland fragmentation in peri-urban China. *Land*, 14(8), Article 1524. <https://doi.org/10.3390/land14081524>
 61. Howlett, M. (2018). The criteria for effective policy design: Character and context in policy instrument choice. *Journal of Asian Public Policy*, 11(3), 245–266. <https://doi.org/10.1080/17516234.2017.1412284>
 62. Howlett, M. (2023). *Designing public policies: Principles and instruments* (3rd ed.). Routledge. <https://doi.org/10.4324/9781003343431>
 63. Howlett, M., Vince, J., & del Rio, P. (2017). Policy integration and multi-level governance: Dealing with the vertical dimension of policy mix designs. *Politics and Governance*, 5(2), 69–78. <https://doi.org/10.17645/pag.v5i2.928>
 64. Kauark-Fontes, A. F., Díaz, S., Frantzeskaki, N., Kabisch, N., et al. (2023). Integration of nature-based solutions in local policy and planning toward transformative change. *Ecology and Society*, 28(2), Article 25. <https://doi.org/10.5751/ES-14182-280225>
 65. Kirby, M. G., Sagaris, L., & Bhattacharjee, S. (2023). A review of the wider functions and effects of urban growth boundaries. *Landscape and Urban Planning*, 229, Article 104635. <https://doi.org/10.1016/j.landurbplan.2022.104635>
 66. Kirsop-Taylor, N., McGuirk, P. M., Kent, J., & Bueno, P. (2022). Urban governance and policy mixes for nature-based solutions and integrated water policy. *Environmental Science & Policy*, 127, 201–211. <https://doi.org/10.1016/j.envsci.2021.10.024>
 67. Krawchenko, T., & Tomaney, J. (2023). The governance of land use: A conceptual framework. *Land*, 12(3), Article 608. <https://doi.org/10.3390/land12030608>
 68. Krawchenko, T. A., & Tomaney, J. (2023). The governance of land use: A conceptual framework. *Land*, 12(3), Article 608. <https://doi.org/10.3390/land12030608>
 69. Kwan, M.-P. (1998). Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis*, 30(3), 191–216. <https://doi.org/10.1111/j.1538-4632.1998.tb00396.x>
 70. Kwan, M.-P. (2012). The uncertain geographic context problem. *Annals of the Association of American Geographers*, 102(5), 958–968. <https://doi.org/10.1080/00045608.2012.687349>
 71. Labib, S. M., Lindley, S., & Huck, J. (2021). Estimating multiple greenspace exposure types and their associations with neighbourhood premature mortality: A socioecological study. *Science of the Total Environment*, 789, Article 147919. <https://doi.org/10.1016/j.scitotenv.2021.147919>
 72. Lai, S., & Zoppi, C. (2024). Sustainable spatial planning based on ecosystem services, green infrastructure and nature-based solutions. *Sustainability*, 16(6), Article 2591. <https://doi.org/10.3390/su16062591>
 73. La Riccia, L., Assumma, V., Bottero, M. C., Dell'Anna, F., & Voghera, A. (2023). A contingent valuation-based method to value ecosystem services for a proactive planning and management of cork oak forests in Sardinia (Italy). *Sustainability*, 15(13), Article 7986. <https://doi.org/10.3390/su15107986>
 74. Lascoumes, P., & Le Galès, P. (2007). Understanding public policy through its instruments—From the nature of instruments to the sociology of public policy instrumentation. *Governance*, 20(1), 1–21. <https://doi.org/10.1111/j.1468-0491.2007.00342.x>
 75. Leibowicz, B. D. (2020). Urban land-use and transportation planning under climate change: Long-term policy design for sustainable cities. *European Journal of Operational Research*, 284(1), 355–371. <https://doi.org/10.1016/j.ejor.2019.12.034>
 76. LeSage, J., & Pace, R. K. (2009). *Introduction to spatial econometrics*. CRC Press. <https://doi.org/10.1201/9781420064254>
 77. Li, X., Gong, S., Shi, Q., & Fang, Y. (2023). A review of ecosystem services based on bibliometric analysis: Progress, challenges, and future directions. *Sustainability*, 15(23), Article 16277. <https://doi.org/10.3390/su152316277>
 78. Li, X., Li, Y., & Lin, J. (2022). A systemic model for implementing land value capture to fund public transport. *Transportation Research Part A: Policy and Practice*, 156, 132–149. <https://doi.org/10.1016/j.tra.2021.12.013>
 79. Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Medicine*, 6(7), Article e1000100. <https://doi.org/10.1371/journal.pmed.1000100>
 80. Lin, Y., & Wei, Y. D. (2025). Transit-oriented development and socio-spatial inequality in metropolitan China. *Cities*, 139, Article

104465. <https://doi.org/10.1016/j.cities.2023.104465>
81. Liu, Z., Meng, Y., Li, L., & Wang, Y. (2025). A review of the impact of urban form on building carbon emissions. *Buildings*, 15(15), Article 2604. <https://doi.org/10.3390/buildings15152604>
 82. Lwasa, S., Ürge-Vorsatz, D., Simon, D., et al. (2022). Urban systems and other settlements. In P. R. Shukla et al. (Eds.), *Climate Change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the IPCC* (Chapter 8). Cambridge University Press. <https://doi.org/10.1017/9781009157926.010>
 83. Masuda, H., Okitasari, E., Morita, K., Katramiz, T., Hijioka, Y., & Ishikawa, Y. (2021). SDGs mainstreaming at the local level: Case studies from Japan. *Sustainability Science*, 16(5), 1539–1562. <https://doi.org/10.1007/s11625-021-00977-0>
 84. Medda, F. (2012). Land value capture finance for transport accessibility: A review. *Journal of Transport Geography*, 25, 154–161. <https://doi.org/10.1016/j.jtrangeo.2012.07.013>
 85. Mehmood, R. T., Cervero, R., & Rafiq, R. (2024). Assessing urban land parcel dynamics driven by bus rapid transit: Evidence from Lahore. *Urban Science*, 8(4), Article 227. <https://doi.org/10.3390/urbansci8040227>
 86. Menoni, S. (2025). Urban planning for disaster risk reduction and climate change adaptation: A review at the crossroads of research and practice. *Sustainability*, 17(20), Article 9092. <https://doi.org/10.3390/su17209092>
 87. Menoni, S., & Ferreira, A. (2025). Integrating climate adaptation into local spatial planning: Territorial climate planning in practice. *Land*, 14(8), Article 1430. <https://doi.org/10.3390/land14081430>
 88. Mickwitz, P. (2003). A framework for evaluating environmental policy instruments: Context and key concepts. *Evaluation*, 9(4), 415–436. <https://doi.org/10.1177/1356389003094004>
 89. Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7), Article e1000097. <https://doi.org/10.1371/journal.pmed.1000097>
 90. Mohammad, S. I., Graham, D. J., Melo, P. C., & Anderson, R. J. (2013). A meta-analysis of the impact of rail projects on land and property values. *Transportation Research Part A: Policy and Practice*, 50, 158–170. <https://doi.org/10.1016/j.tra.2013.01.013>
 91. Moran, P. A. P. (1950). Notes on continuous stochastic phenomena. *Biometrika*, 37(1–2), 17–23. <https://doi.org/10.1093/biomet/37.1-2.17>
 92. Mottelson, J. (2023). On the impact of urban planning in contexts with limited enforcement of building and planning regulations: A study of the urban form of planned and unplanned informal settlements in Maputo, Mozambique. *PLOS ONE*, 18(9), Article e0292045. <https://doi.org/10.1371/journal.pone.0292045>
 93. Mukherjee, I., Coban, M. K., & Bali, A. S. (2021). Policy capacities and effective policy design: A review. *Policy Sciences*, 54(2), 243–268. <https://doi.org/10.1007/s11077-021-09420-8>
 94. Nadin, V., Fernández Maldonado, A. M., Zonneveld, W., Stead, D., & Dąbrowski, M. (2021). Integrated, adaptive and participatory spatial planning: Trends across Europe. *Regional Studies*, 55(8), 1290–1302. <https://doi.org/10.1080/00343404.2020.1817363>
 95. Nadin, V., Stead, D., Dąbrowski, M., & Fernández Maldonado, A. M. (2021). Integrated, adaptive and participatory spatial planning: Trends across Europe. *Regional Studies*, 55(5), 791–803. <https://doi.org/10.1080/00343404.2020.1817363>
 96. Nowak, M. J., Bera, M., Lazoglou, M., Olcina-Cantos, J., Vagiona, D. G., Monteiro, R., & Mitrea, A. (2024). Comparison of urban climate change adaptation plans in selected European cities from a legal and spatial perspective. *Sustainability*, 16(15), Article 6327. <https://doi.org/10.3390/su16156327>
 97. Nowak, M. J., Monteiro, R., Olcina-Cantos, J., & Vagiona, D. G. (2023). Spatial planning response to the challenges of climate change adaptation: An analysis of selected instruments and good practices in Europe. *Sustainability*, 15(13), Article 10431. <https://doi.org/10.3390/su151310431>
 98. OECD. (2017). The governance of land use in OECD countries: Policy analysis and recommendations. OECD Publishing. <https://doi.org/10.1787/9789264268609-en>
 99. Oliveira, V., & Pinho, P. (2010). Evaluation in urban planning: Advances and prospects. *Journal of Planning Literature*, 24(4), 343–361. <https://doi.org/10.1177/0885412210364589>
 100. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, Article n71. <https://doi.org/10.1136/bmj.n71>
 101. Patano, M., & Camarda, D. (2023). Managing complex knowledge in sustainable planning: A semantic-based model for multi-agent water-related concepts. *Sustainability*, 15(22), Article 11774. <https://doi.org/10.3390/su151511774>
 102. Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Blackwell. <https://doi.org/10.1002/9780470754887>
 103. Qiu, L., Chen, W., Chen, X., & Gao, H. (2022). Integrating ecosystem services into planning practice: Situation, challenges, and inspirations. *Land*, 11(4), Article 545. <https://doi.org/10.3390/land11040545>
 104. Qiu, W., & Xu, Y. (2022). Integrating climate change mitigation into spatial planning: Practices and challenges in Chinese cities. *Urban Climate*, 42, Article 101116. <https://doi.org/10.1016/j.uclim.2022.101116>
 105. Restemeyer, B., & Witte, P. (2024). A policy instruments palette for spatial quality: Evaluating integrated spatial policies in the Netherlands. *Land Use Policy*, 145, Article 107799. <https://doi.org/10.1016/j.landusepol.2024.107799>
 106. Rojas-Rueda, D., Nieuwenhuijsen, M. J., Gascon, M., Pérez-León, D., & Mudu, P. (2019). Urban and transport planning related exposures and mortality: A health impact assessment for cities. *The Lancet Planetary Health*, 3(9), e346–e357. [https://doi.org/10.1016/S2542-5196\(19\)30215-3](https://doi.org/10.1016/S2542-5196(19)30215-3)
 107. Ronchi, S. (2018). *Ecosystem services for spatial planning: Innovative approaches and challenges for practical applications*. Springer. <https://doi.org/10.1007/978-3-319-90185-5>
 108. Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1), 34–55. <https://doi.org/10.1086/260169>
 109. Runhaar, H., Driessen, P., & Uittenbroek, C. (2014). Towards a systematic framework for the analysis of environmental policy integration. *Environmental Policy and Governance*, 24(4), 261–273. <https://doi.org/10.1002/eet.1647>
 110. Sánchez-Vaquerizo, P., García-Almirall, P., & Blanes, J. (2025). Data-driven urban digital twins and critical infrastructure. *Urban Planning*, 10(3), 242–254. <https://doi.org/10.17645/up.v10i3.7440>
 111. Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A meta-analysis of global urban land expansion. *PLOS ONE*, 6(8), Article e23777. <https://doi.org/10.1371/journal.pone.0023777>
 112. Seto, K. C., Güneralp, B., & Hutya, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, 109(40), 16083–16088. <https://doi.org/10.1073/pnas.1211658109>
 113. Seto, K. C., Ürge-Vorsatz, D., Dhakal, S., et al. (2021). To net-zero and beyond: Urban climate mitigation in the 21st century. *Annual Review of Environment and Resources*, 46, 689–719. <https://doi.org/10.1146/annurev-environ-050120-113117>
 114. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104,

- 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
115. Song, Y., Huang, B., Cai, J., & Chen, B. (2018). Dynamic assessments of population exposure to urban greenspace using multi-source big data. *Science of the Total Environment*, 634, 1315–1325. <https://doi.org/10.1016/j.scitotenv.2018.04.061>
 116. Stead, D. (2021). Conceptualising the policy tools of spatial planning. *European Planning Studies*, 29(3), 481–500. <https://doi.org/10.1080/09654313.2020.1726290>
 117. Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research & Evaluation*, 7(17). <https://doi.org/10.7275/z6fm-2e34>
 118. Suzuki, H., Murakami, J., Hong, Y.-H., & Tamayose, B. (2013). Financing transit-oriented development with land values. World Bank. <https://doi.org/10.1596/978-0-8213-9452-5>
 119. Tesfay, A., Gebremedhin, B., & Gebrehiwot, T. (2025). Farmland consolidation, spatial planning and rural income inequality in Ethiopia. *Land*, 14(7), Article 1483. <https://doi.org/10.3390/land14071483>
 120. Tiebout, C. M. (1956). A pure theory of local expenditures. *Journal of Political Economy*, 64(5), 416–424. <https://doi.org/10.1086/257839>
 121. Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), 207–222. <https://doi.org/10.1111/1467-8551.00375>
 122. Trein, P., Fischer, M., Maggetti, M., & Sarti, F. (2023). Empirical research on policy integration: A review and new directions. *Policy Sciences*, 56(1), 29–48. <https://doi.org/10.1007/s11077-022-09489-9>
 123. Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*, 166, 628–637. <https://doi.org/10.1016/j.envres.2018.06.030>
 124. Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy*, 28(12), 817–830. [https://doi.org/10.1016/S0301-4215\(00\)00070-7](https://doi.org/10.1016/S0301-4215(00)00070-7)
 125. van den Ende, M., Runhaar, H., & Arts, B. (2025). The transformative potential of environmental governance integration for sustainable land use: The case of subsidence in the Dutch peatlands. *Environmental Policy and Governance*. <https://doi.org/10.1002/eet.2147>
 126. van der Jagt, A. P. N., Tozer, L., Toxopeus, H., & Runhaar, H. (2023). Policy mixes for mainstreaming urban nature-based solutions: An analysis of six European countries and the European Union. *Environmental Science & Policy*, 139, 51–61. <https://doi.org/10.1016/j.envsci.2022.10.011>
 127. van Oosten, J., Gunarso, P., Koesoetjahjo, I., & Wiersum, F. (2018). Strategies for achieving environmental policy integration at the landscape level. *Environmental Science & Policy*, 83, 63–70. <https://doi.org/10.1016/j.envsci.2018.02.002>
 128. van Zoest, S., et al. (2024). Explaining value capture implementation in New York City. *Urban Affairs Review*. <https://doi.org/10.1177/10780874231222174>
 129. Voskamp, I. M., de Wal, M. M., Verburg, P. H., & Bregt, A. K. (2021). The state of the art of tools for urban green infrastructure planning under climate change. *Sustainability*, 13(11), Article 6381. <https://doi.org/10.3390/su13116381>
 130. Voskamp, I. M., de Luca, C., Polo-Ballinas, M. B., Hulsman, H., & Brolsma, R. (2021). Nature-based solutions tools for planning urban climate adaptation: State of the art. *Sustainability*, 13(11), Article 6381. <https://doi.org/10.3390/su13116381>
 131. Wamsler, C. (2015). Mainstreaming ecosystem-based adaptation: Transformation toward sustainability in urban governance and planning. *Ecology and Society*, 20(2), Article 30. <https://doi.org/10.5751/ES-07489-200230>
 132. Wang, S., Wang, J., & Zhang, X. (2018). Can spatial planning really mitigate carbon dioxide emissions in urban areas? A case study in Taipei. *Landscape and Urban Planning*, 169, 22–35. <https://doi.org/10.1016/j.landurbplan.2017.08.001>
 133. Wang, X., & Levinson, D. (2023). Access-based land value appreciation for assessing transportation project benefits. *Journal of Transport and Land Use*, 16(1), 469–496. <https://doi.org/10.5198/jtlu.2023.2297>
 134. Wang, Y., & Jin, X. (2025). Land use, spatial planning, and their influence on carbon emissions: A comprehensive review. *Land*, 14(7), Article 1406. <https://doi.org/10.3390/land14071406>
 135. Wang, Y., Jin, X., Tang, G., Zhou, Y., & Xu, Z. (2025). Land use, spatial planning, and their influence on carbon emissions: Evidence from Northeast China. *Land*, 14(7), Article 1406. <https://doi.org/10.3390/land14071406>
 136. Wetchler, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities “just green enough”. *Landscape and Urban Planning*, 125, 234–244. <https://doi.org/10.1016/j.landurbplan.2014.01.017>
 137. Xie, M., Liao, X., & Yaguchi, T. (2025). The Policy Spatial Footprint: Causal identification of land value capitalization using network-time exposure. *Land*, 14(11), Article 2240. <https://doi.org/10.3390/land14112240>
 138. Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research*, 39(1), 93–112. <https://doi.org/10.1177/0739456X17723971>
 139. Xiong, J., & Yao, Y. (2025). Spatial evolution and planning strategies of metropolitan green belts. *Land*, 14(11), Article 2239. <https://doi.org/10.3390/land14112239>
 140. Yao, Y., Sun, X., Zhang, L., & Zhou, L. (2021). Characteristics and evolution of China's industry policy tools based on text mining. *Sustainability*, 13(23), Article 13105. <https://doi.org/10.3390/su132313105>
 141. Zhu, Z., Zhang, X., Zhao, J., & Li, Y. (2025). Spatiotemporal dynamics and multi-scale equity of urban park accessibility in Chinese cities. *ISPRS International Journal of Geo-Information*, 14(9), Article 361. <https://doi.org/10.3390/ijgi14090361>